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LIMNOLOGY OF TAYLOR CREEK IMPOUNDMENT WITH REFERENCE TO OTHER W--ETC(U)

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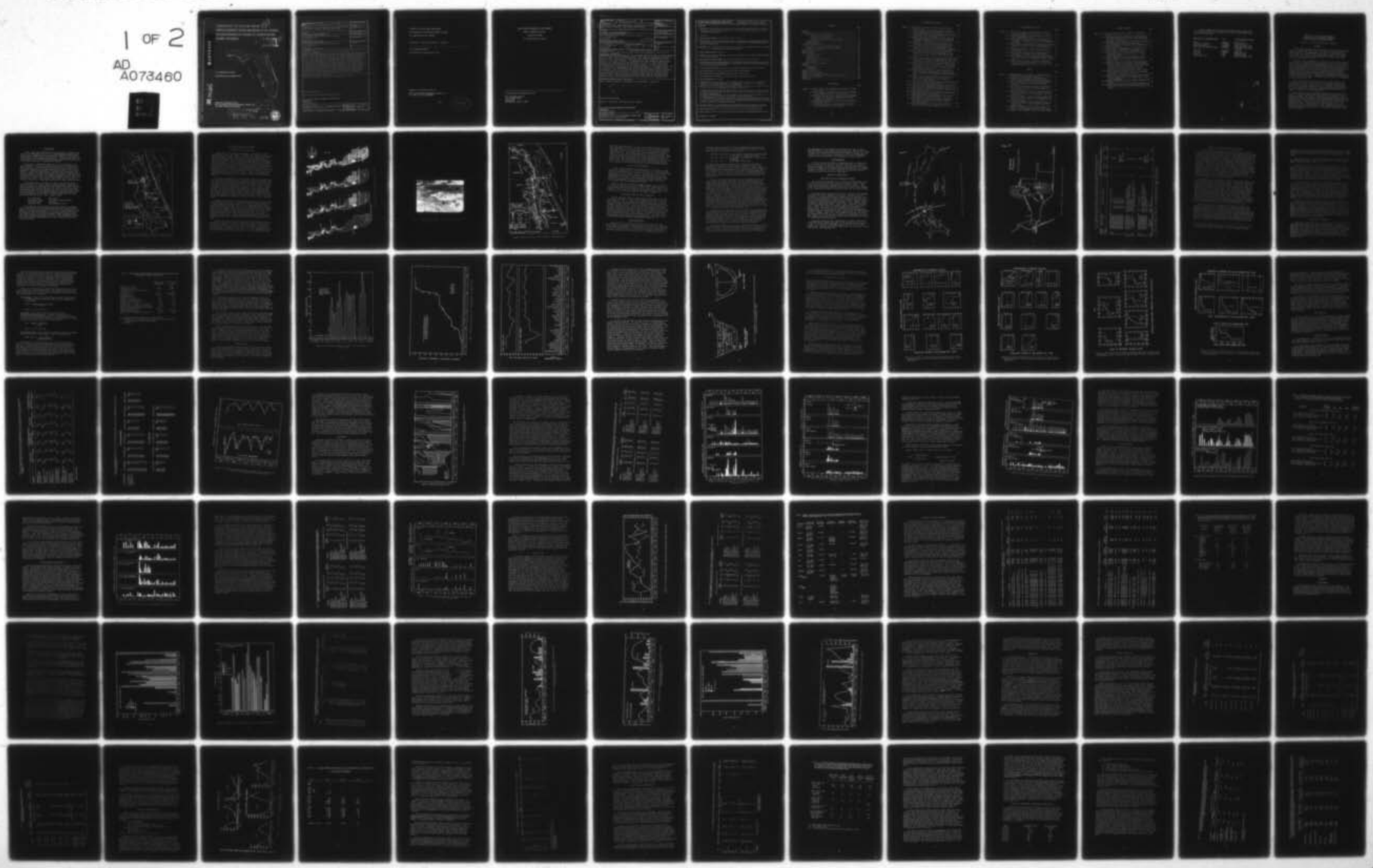

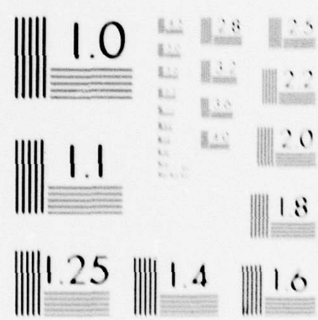

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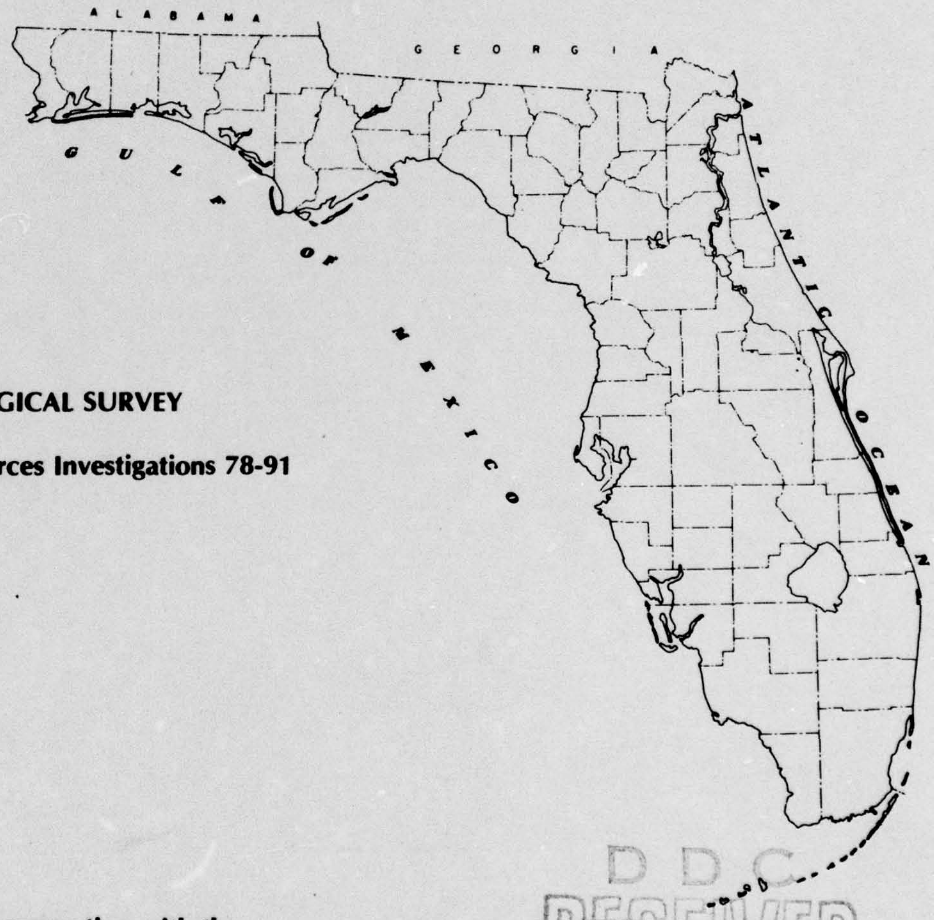

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ILLUSTRATIONS

TABLES

For those readers who may prefer to use metric units rather than U.S. customary units, the conversion factors for the terms used in this report are listed below:

Multiply U.S. customary units	By	To obtain metric units
acre	4.405×10^{-1}	hectare (ha)
acre-foot (acre-ft)	1.233×10^{3}	cubic meter (m^3)
acre-foot (acre-ft)	1.233×10^{-3}	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	2.832×10^{-2}	cubic meter per second (m^3/s)
foot (ft)	3.048×10^{-1}	meter (m)
inch (in)	2.540×10^{1}	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

LIMNOLOGY OF TAYLOR CREEK IMPOUNDMENT WITH REFERENCE TO OTHER WATER BODIES IN UPPER ST. JOHNS RIVER BASIN, FLORIDA

By Donald A. Goolsby and Benjamin F. McPherson

ABSTRACT

Taylor Creek Impoundment was constructed on the western side of the upper St. Johns River basin as part of a plan for flood control and water regulation. The impoundment, which has a surface area of about 4,000 acres, was initially filled late in 1969. Water of relatively poor quality was observed in the impoundment during its first three years of its existence (1970-72).

The depth of the impoundment is sufficient to allow thermal stratification, and a thermocline usually develops at depths of 8 to 10 feet. During 1970-72 the hypolimnion remained anaerobic for more than half the year. The hypolimnion also accumulated high concentrations of phosphorus, ammonia-nitrogen, carbon dioxide, ferrous iron, hydrogen sulfide and other substances. The poor water quality is attributed to the decomposition of flooded vegetation, decomposition of soil organic matter, and heavy growths of phytoplankton and duckweed stimulated by an abundant supply of nutrients. Flushing of the impoundment and depletion of leachable nutrients and soil organic matter have led to an improvement in water quality since 1972.

During 1973 and 1974 the depth to the top of the anaerobic zone increased to more than 12 feet and by 1974 the period of anaerobiosis decreased to less than 2 months out of 12. Phosphorus concentration after the fall overturn decreased more than 50 percent between 1970 and 1974. The reduction in biochemical oxygen demand during this period suggests a decrease in primary productivity.

Water released from the impoundment during the period 1969-75 was similar in quality to nearby Wolf Creek and Jane Green Creek. Of 21 physical, organic, and inorganic constituents, only ammonia-nitrogen was significantly higher in releases from the impoundment than it was in the natural streams. Dissolved oxygen was higher in water released from the impoundment than in the natural streams and dissolved solids concentration were lower. Large releases from the impoundment may, under certain conditions, produce velocities great enough to resuspend bottom sediments several miles downstream at a point where Taylor Creek flows into Lake Poinsett.

INTRODUCTION

The St. Johns River originates in a wide expanse of marshes northeast of Lake Okeechobee (fig. 1). From these headwater marshes, water flows slowly northward 30 to 40 miles to the vicinity of Lake Hellen Blazes where a river channel first develops. From this point the river flows northward more than 300 river miles and ultimately discharges into the Atlantic Ocean east of Jacksonville, Florida.

The upper St. Johns River basin (fig. 1) has a drainage area of about 2,000 mi^2. The basin is bounded on the east by a coastal ridge which separates it from the Indian River basin, and on the west by a ridge which separates it from the Kissimmee River basin. The southern boundary is poorly defined because of extremely flat topography. The upper St. Johns River, which includes that part south of Lake Harney, is characterized by an extremely low hydraulic gradient of about 0.2 ft per mi (Brown and others, 1962). The headwater marshes are only about 25 ft above mean sea level. Lake Harney at the northern end of the area is normally less than 6 ft above mean sea level, but rarely below sea level.

The northern part of the upper St. Johns River basin includes a river flood plain, or valley, and well-drained uplands. Marsh land is confined primarily to areas near the river channel, and prairie and pine forest occupy much of the flood plain. The river in this region flows through Lake Hellen Blazes, Sawgrass Lake, Lake Washington, Lake Winder, and Lake Poinsett. The well-drained uplands are most prominent along the western boundary of the basin. Several streams drain from these western uplands into the St. Johns. These include:

Ft. Drum Creek	Wolf Creek
Blue Cypress Creek	Taylor Creek (now impounded)
Jane Green Creek	Jim Creek
Pennywash Creek	Econlockhatchee River

The flood plain of the southern part of the basin is a headwater marsh. Blue Cypress Lake, the only large open body of water in this region, is located on the western side of the St. Johns headwaters marsh just north of State Road 60 (fig. 1). The lake receives inflow from Blue Cypress Creek, Ft. Drum Creek, Padgett Branch and some overland flow from the marsh areas south of the lake. Water discharges from the lake to the north through marshes and a canal, into the area south of Lake Hellen Blazes.

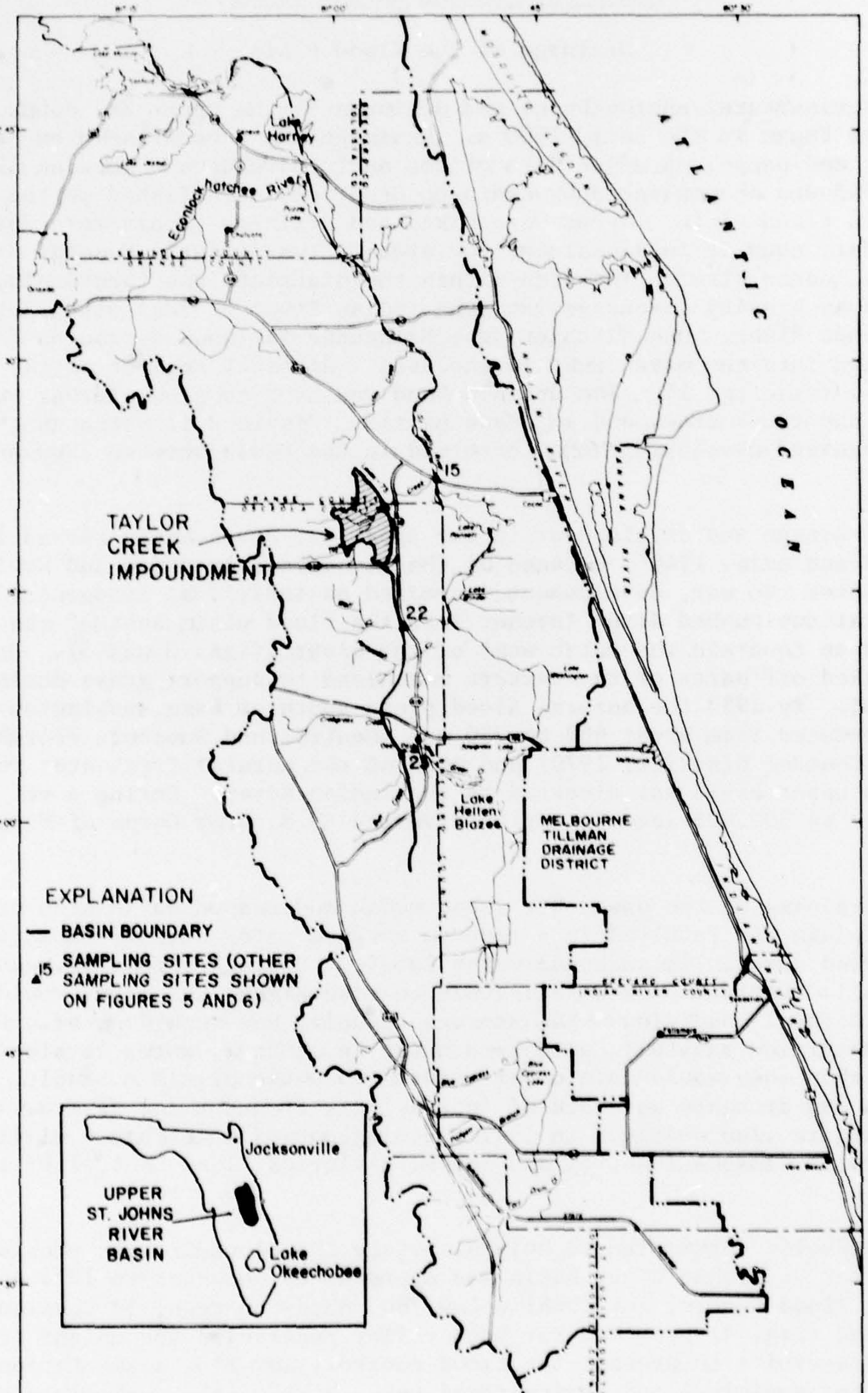

Figure 1.--Taylor Creek Impoundment and upper St. Johns River basin.

Man's Alterations in the Basin

Drainage of the Flood Plain

Agricultural encroachment and drainage of the upper St. Johns marshes began in the early 1900's. Drainage was accomplished by canals, dikes, and pumps. A major part of the early development between 1910 and 1945 was accomplished by drainage districts established on the eastern flood plain. Areas were diked and drainage canals were dug to the east, usually in a swale or low area of the Atlantic Coastal Ridge, to the Indian River. The area within the districts was then drained mainly by gravity discharge into the Indian River or less often into the St. Johns River. One district, the Melbourne-Tillman, spread so far westward into the marsh that it enclosed a distinct segment of the river channel (see fig. 1). The drained land was used to grow citrus, sugarcane, and truck crops and to graze cattle. Figure 2 illustrates the drainage and development that occurred in the basin between 1900 and 1972.

Drainage and development in the upper St. Johns basin slowed in the 1930's and early 1940's because of the economic depression and World War II. After the war, development increased as individual landowners and corporations pushed dikes farther into the flood plain east of the river and began to drain the marsh west of the river (figs. 2 and 3). Ranchers diked off parts of the western marshland to support grass during drought. By 1957 the natural flood plain south of Lake Washington had been reduced from about 680 to 250 mi^2 (Central and Southern Florida Flood Control District, 1970) and much of the natural freshwater runoff in the upper basin was diverted to the Indian River. During a wet year as much as 300,000 acre-ft may be diverted (U.S. Army Corps of Engineers, 1957).

Drainage of the upper St. Johns marsh and reduction in size of the flood plain has resulted in a reduced surface water storage capacity and in marked changes in seasonal water levels. During periods of heavy rainfall, runoff causes water levels to rise higher than they would have under natural conditions when storage capacity was much greater. During periods of low rainfall, with less water in storage, water levels drop lower than they would have under natural conditions. As a result, floods and droughts have become increasingly frequent and severe. The flooding is also costly. In 1947 flooding caused more than 4 million dollars in damages (Central and Southern Florida Flood Control District, 1970).

A public works plan to help alleviate the flood-drought problems in the upper St. Johns River basin was approved by Congress in 1954 as part of the Flood Control Act (Public Law 780, 83rd Congress, 2d Session). The plan (fig. 4) provided for both valley reservoirs and upland tributary reservoirs to provide for flood control, low-flow augmentation, and water for municipal and agricultural use. Part of the authorized works

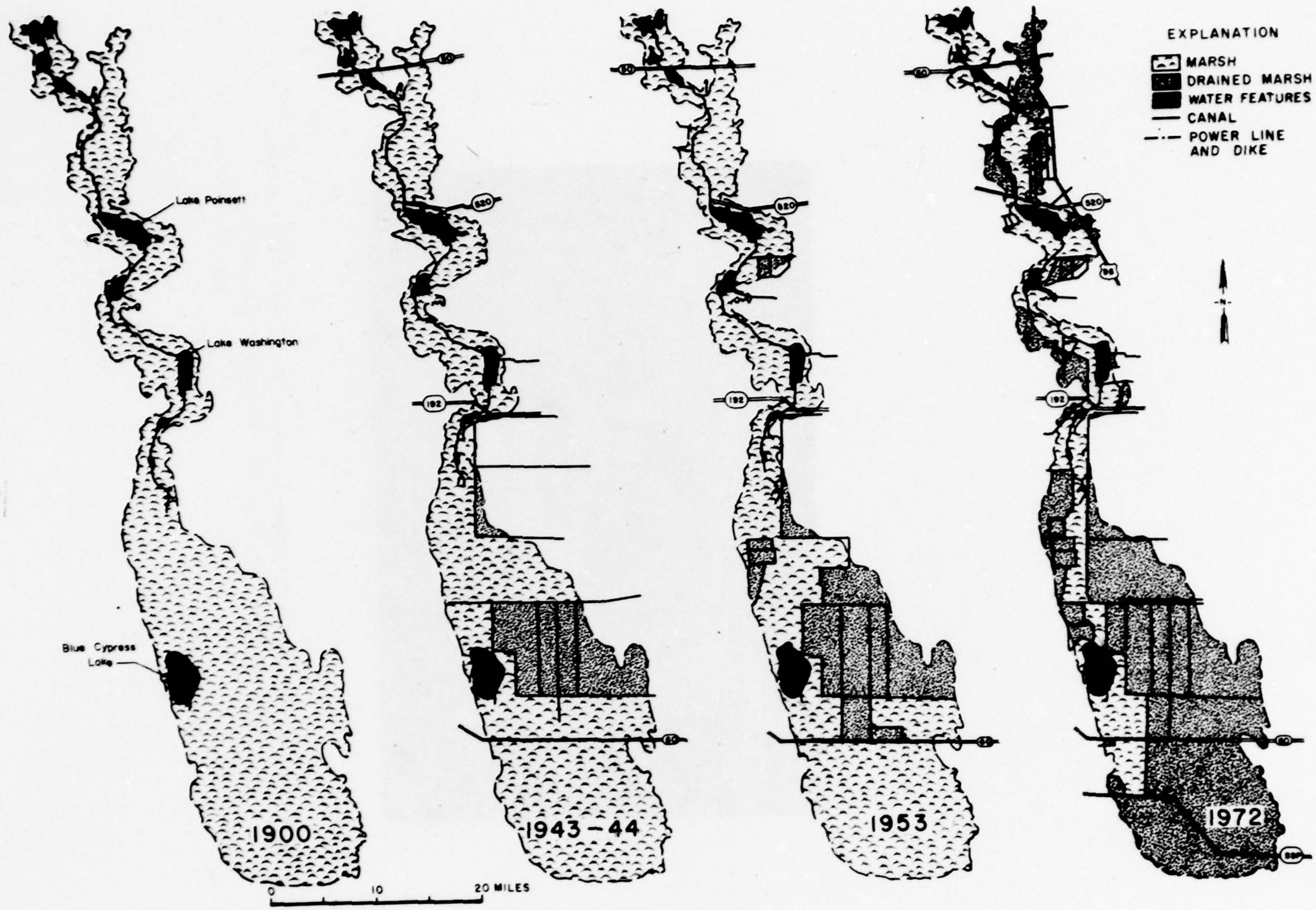

Figure 2.--Upper St. Johns River marsh, 1900 and 1943-44, 1953, and 1972.

Figure 3.--Agricultural drainage in upper St. Johns River marsh, south of State Highway 60, September 27, 1971.

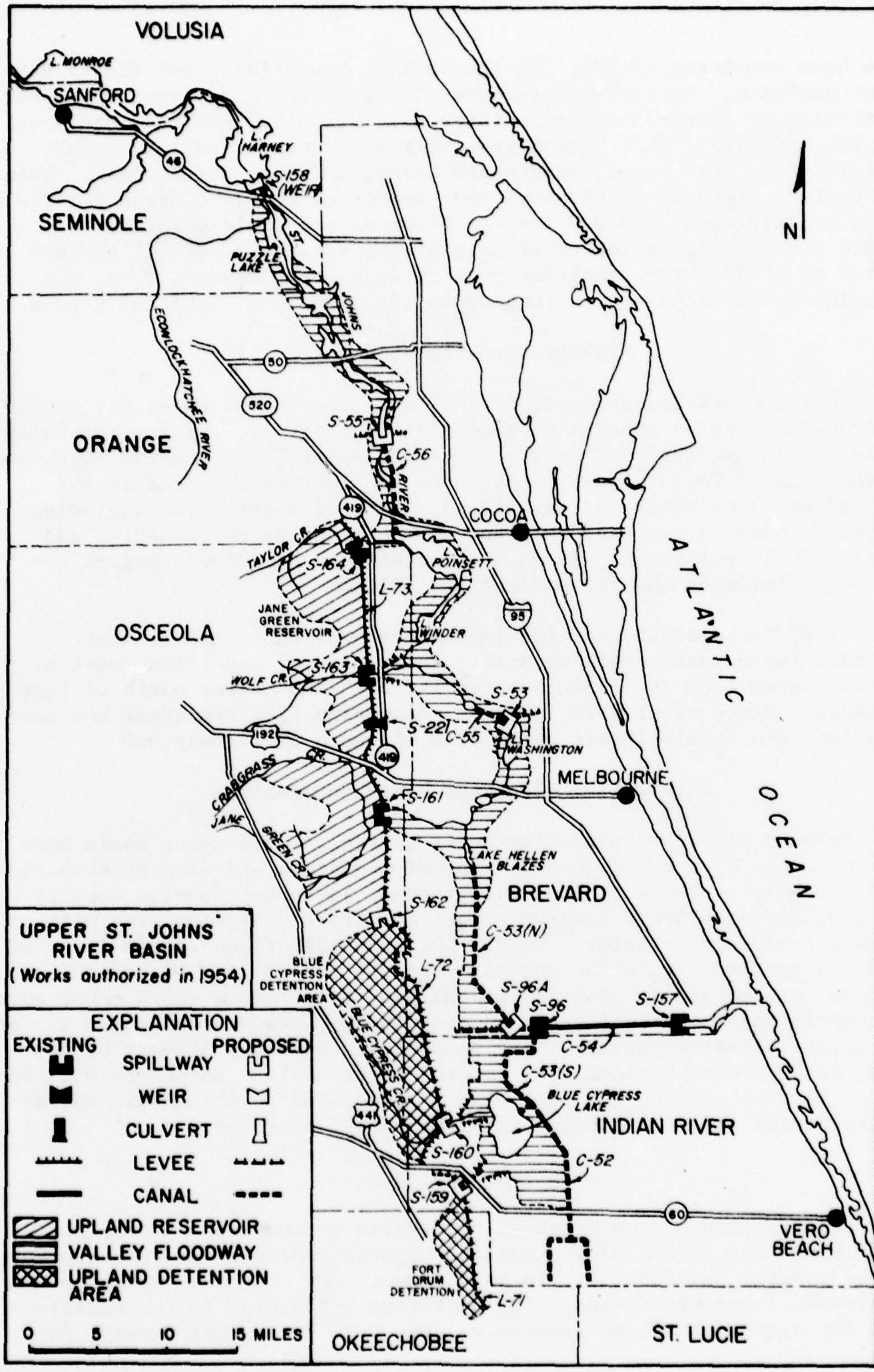

Figure 4.--Flood Control Plan (1970) for upper St. Johns River basin.

have been completed (1977). In the valley, Sebastian Canal (C-54) has been completed. On the western side of the basin, Jane Green Reservoir, consisting of levee-73 and structures 161, 221, 163, and 164, has been completed (1977). This upland reservoir was constructed to impound Taylor Creek, Wolf Creek, Penneywash Creek, and Jane Green Creek. When filled to a stage of 46 ft above mean sea level the Jane Green Reservoir would contain about 245,000 acre-ft of water and would cover about 27,000 acres. The Taylor Creek part of the reservoir was filled late in 1969. As of 1977 the remaining part of Jane Green Reservoir had not been impounded because of strong opposition from environmental groups.

Taylor Creek Impoundment

Taylor Creek Impoundment, on the west side of the upper St. Johns River basin, drains an area of about 52 mi^2 (fig. 1). It was initially filled in Autumn 1969 and covers parts of Taylor Creek and the north and south forks of Taylor Creek. Little or no clearing was done in the impoundment area before it was filled. Natural vegetation, including hardwoods such as cypress, oak, and gum near the creek channels, and mostly pines, palmettos, and natural grasses at higher elevations, was inundated when the impoundment was filled.

Water is released from the impoundment through control structure 164 into the natural creek channel. Under natural conditions most of the discharge from the creek entered the St. Johns River north of Lake Poinsett. Since about 1970, however, discharge from the creek has been diverted into Lake Poinsett about 0.75 mi south of Highway 520.

Alternative Plans for Water Management

Several alternate plans for water control in the upper basin have been proposed by the U.S. Army, Corps of Engineers and also by several State agencies. There is general agreement in these plans to operate the proposed Jane Green Reservoir as a temporary detention area with no permanent storage of water. Under this proposal, flood waters would be detained temporarily in the upland reservoir for periods of as much as 90 days to prevent flooding in the valley. Only floods which occur more frequently than once in 5 years to once in 10 years would require use of the upland detention areas. This proposal is included as part of the Corps of Engineers revised plan for the upper basin. No action will be taken, however, unless the full plan is presented to the public and an environmental impact statement is prepared and approved.

Purpose and Scope

Construction of the proposed reservoirs in the upper St. Johns River basin has raised many questions regarding effects of the reservoirs on the aquatic environment. To help answer some of these questions and to provide a scientific basis for decisions pertaining to the construction and operation of the reservoirs, the U.S. Geological Survey, in

cooperation with the South Florida Water Management District and the U.S. Army, Corps of Engineers, conducted several investigations in the basin from July 1969 to July 1975 as follows:

July 1969 - June 1971	A water-quality reconnaissance investigation of the upper St. Johns River basin.
July 1971 - July 1973	An intensive investigation of Taylor Creek Impoundment.
July 1973 - 1976	Water-quality monitoring.

The 1969-71 water-quality reconnaissance investigation was made to qualitatively assess the existing chemical quality, biologic, and environmental conditions in the upper St. Johns River basin. Results of this reconnaissance, documented by Goolsby and McPherson (1970) show that the water in the then newly-formed Taylor Creek Impoundment was of poor quality. Evidence for poor water quality included low dissolved oxygen concentrations, chemical stratification, and high nutrient concentrations.

Because of the poor water quality in the impoundment and because water in the other upland reservoirs yet to be completed would, no doubt, present problems, an intensive limnological investigation was conducted in the impoundment between July 1971 and July 1973. Objectives of the study were to: (1) document chemical and biological conditions in the impoundment, (2) define the areal and seasonal patterns of stratification, (3) examine the effects on downstream water quality of releases from the impoundment, and (4) determine how releases could best be made so as not to adversely affect the quality of the water in the St. Johns River. Blue Cypress Lake was included in the study as a control to provide concurrent chemical and biological information on a nearby natural water body. Although there are important limnological differences between Blue Cypress Lake and Taylor Creek Impoundment, both are in the same major drainage basin and the lake is reasonably representative of the typically shallow, nonstratified water bodies in the area. Data were also needed on Blue Cypress Lake because it, too, would be affected by the proposed water management plans.

In addition to the intensive study of Taylor Creek Impoundment and Blue Cypress Lake, data have also been collected at bimonthly intervals from Wolf Creek, Jane Green Creek, and from several points on the main stem of the St. Johns River since 1971 as part of a separate long-term monitoring program in the basin. These additional data add materially to the understanding of Taylor Creek Impoundment. Upon completion of the intensive study in 1973, stations in the impoundment and Blue Cypress Lake were added to the long-term monitoring program.

This report presents the results of chemical and biological investigations made in Taylor Creek Impoundment from its initial filling in 1969 to July 1975. Comparisons are made between the impoundment and Blue Cypress Lake and, where appropriate, the quality of the water in

the impoundment is also compared with streams in the area and with published data on various lakes in central Florida. Much of this report is based on the data from the intensive investigation between July 1971 and July 1973. Descriptions of long-term (5 to 6 years) limnological changes which have occurred in the impoundment are also presented.

Acknowledgments

We thank the South Florida Water Management District (SFWMD) and the U.S. Army Corps of Engineers for their cooperation and support during this study. We are also indebted to Robert Taylor and Richard Irons of the SFWMD for furnishing stage and discharge data and to SFWMD personnel at Melbourne for their assistance in providing controlled releases of water for Taylor Creek Impoundment.

METHODS OF INVESTIGATION

Locations of Sites and Sampling Frequency

The locations of sampling sites in Taylor Creek Impoundment, Lake Poinett, and Blue Cypress Lake are shown in figures 5 and 6. Other sites sampled during the investigation are shown in figure 1. These sites and the approximate sampling frequencies for the various segments of the investigation between July 1969 and June 1975 are given in table 1.

The water-quality constituents which were measured varied somewhat throughout the various segments of the study. Generally, specific conductance, pH, dissolved oxygen and temperature were measured in the field on each sampling trip. Samples were analyzed in the laboratory for nitrogen and phosphorus species (nitrate, nitrite, ammonia, organic-nitrogen, orthophosphate and total phosphorus), total organic carbon, biochemical oxygen demand (BOD), silica, color, turbidity, and alkalinity. Samples collected at the primary sampling sites, marked ** on table 1, were also analyzed for the dominant type and numbers of phytoplankton. The major chemical constituents (calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride) and trace elements (arsenic, cadmium, copper, iron, lead, manganese, mercury, and zinc) were measured four times each year during the reconnaissance and intensive studies and twice each year--in about May and September--as part of the continuing monitoring program.

During the intensive study, measurements of primary productivity (light-dark bottle method) were made on each sampling trip at sites 1, 2, and 3 in Taylor Creek Impoundment and at sites 16 and 17 in Blue Cypress Lake. Benthic invertebrate samples were also collected at these five sites on each sampling trip.

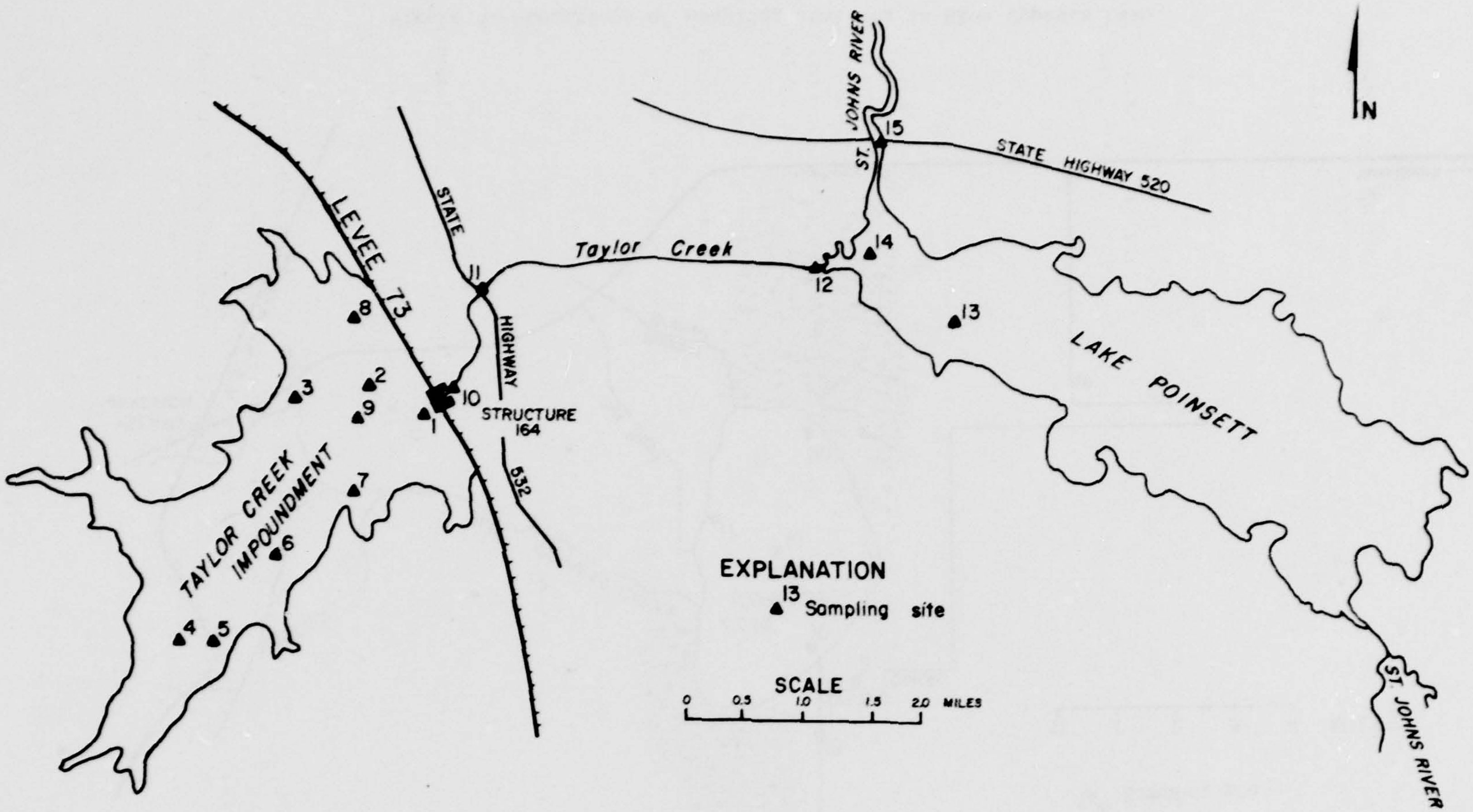

Figure 5.--Locations of sampling stations in Taylor Creek Impoundment.

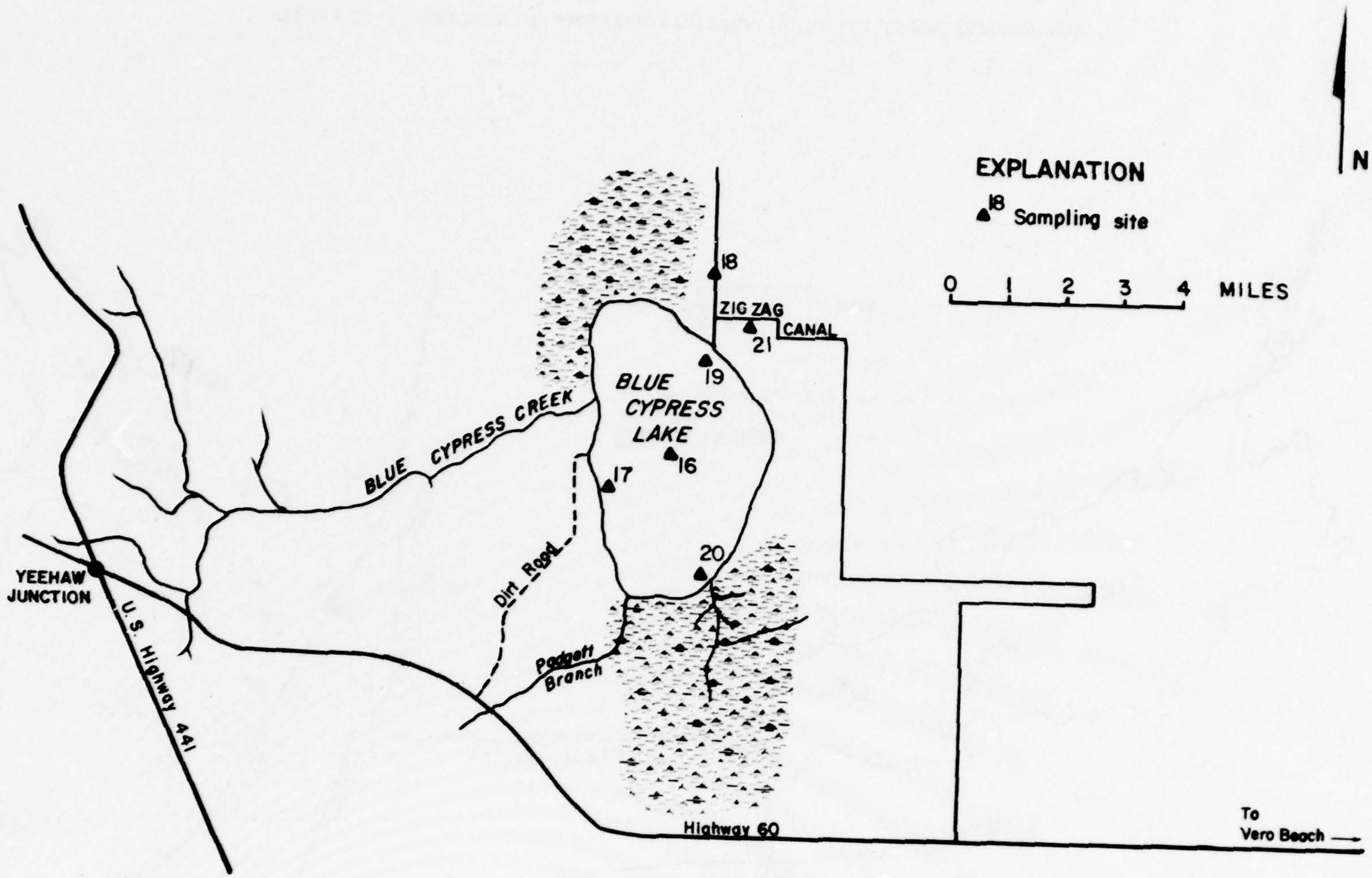

Figure 6.--Locations of sampling stations in Blue Cypress Lake.

Table 1.--Sampling site in the upper St. Johns River basin and approximate sampling frequencies.

(B, bimonthly; B+, bimonthly plus monthly sampling during summer months; Q, quarterly).

Number on map (site number)	Site identcation number	Name and Location	APPROXIMATE SAMPLING FREQUENCY 7-69 to 6-70	7-70 to 6-71	7-71 to 9-72	10-72 to 6-75
1**	282020080561500 a/	Taylor Creek Impoundment,	Q	B	B+	B
2**	282035080564500	Do.,	-	-	B+	-
3**	282040080571000	Do., Site 3	-	-	B+	B
4	28135080581000	Do., Site 4	-	-		-
5	281835080575000	Do., Site 5	-	-		-
6	281910080572500	Do., Site 6	-	-	Sampled	-
7	282010080564500	Do., Site 7	-	-	one or	-
8	282055080564500	Do., Site 8	-	-	more times	-
9	282035080561500	Do., Site 9	-	-		-
10**	282025080560100	Taylor Creek below S-164	-	-	B	B
11	282110080554500	Taylor Creek at Highway 532	-	-	B	-
12	282117080523000	Taylor Creek at Lake Poinsett	-	-	B	-
13	02232300	Lake Poinsett	Q	-	B	-
14	282125080522000	Lake Poinsett below Taylor Creek	-	-	B	-
15**	02232400	St. Johns River near Cocoa	Q	B	B	B
16**	274340080453500 b/	Blue Cypress Lake,	Q	B	B+	B
17**	274350080462000	Do.,	-	-	B+	-
18	274730080443800	Blue Cypress Lake Outlet Canal	-	-		-
19	274505080444000	Blue Cypress Lake at Outlet	-	-	Sampled	-
20	274159080443800	Blue Cypress Lake Site 5	-	-	one or	-
21	274520080443000	Zig Zag Canal	-	-	more times	-
22	02232200	Wolf Creek	Q	-	B	B
23**	02231600	Jane Green Creek	Q	B	B	B

**Primary sampling station

a/ From July 1969 to July 1971, site identification number was 02232413.
b/ From July 1969 to July 1971, site identification number was 02331400.

Sampling Collection and Analysis Methods

Dissolved oxygen and temperature were measured in place with a Yellow Springs Instrument Company model 54[1] meter equipped with a DO and temperature probe and submersible stirrer. Measurements of pH were made immediately after sample collection with an Orion model 401[1] pH meter. A flow-through cell arrangement connected to a portable peristaltic pump was used in measuring pH and Eh (oxidation-reduction potential) in vertical profiles in Taylor Creek Impoundment. This enabled measurement of these two parameters before the sample came in contact with the atmosphere. Eh was measured with an Orion model 401[1] pH meter using a platinum electrode and calomel reference electrode. Potentials measured against the calomel reference electrode were converted to Eh by adding 245 millivolts to the measured value to correct for the potential of the calomel electrode. Specific conductance was measured with either a Lab-Line Mark 5[1] specific conductance meter or a Yellow Springs SCT[1] conductance meter. Water transparency was measured with a secchi disc having alternating black and white quadrants.

All samples for chemical analysis were collected with either a non-metallic point sampler (WILDCO[1] model 1540), a polyethylene bottle held in a weighted sampler, or a peristaltic pump. Samples from discrete depths were collected with the point sampler or peristaltic pump. The weighted bottle sampler was used to collect depth-integrated samples from all or part of the water column. Unfiltered samples for nitrogen and phosphorus species, silica, BOD, color, turbidity, and alkalinity were stored in polyethylene bottles which had been thoroughly rinsed with the sample and immediately placed in an ice chest. Unfiltered samples for analysis of total organic carbon were stored in specially cleaned glass vials and stored in an ice chest. The BOD analysis was started within 24 hours after the sample was collected and the remaining analyses were usually made within 72 hours after collection. Samples were refrigerated and stored in the dark until analysis began.

Samples for analysis of anions such as chloride, sulfate, and fluoride, and dissolved solids residue, were filtered through a 0.45-micrometer membrane filter and stored in rinsed polyethylene bottles. Samples for cation analysis (calcium, magnesium, sodium, potassium), and dissolved trace metals, were filtered through a 0.45-micrometer membrane filter, stored in acid-rinsed polyethylene bottles and acidified to a pH less than 2 with double distilled nitric acid. Samples for total metals analysis (dissolved plus suspended metals, lead, cadmium, mercury, and others) were stored in acid-rinsed bottles without filtration and were

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[1] The use of brand-named products in this report is for identification only and does not imply endorsement by the U.S. Geological Survey.

acidified to a pH less than 2 with double distilled nitric acid. Chemical analyses for the major cations and anions were usually completed within 2 to 4 weeks; trace metal analyses were usually completed within 3 to 6 weeks.

Laboratory analytical methods used during this study are given in Brown and others (1970), Goerlitz and others (1972), and U.S. Environmental Protection Agency (1971).

Phytoplankton samples were collected from the upper 3 ft of the water column in 1-liter polyethylene bottles. Samples were preserved with 3 ml (milliliters) of 2 percent fomaldehyde solution, 0.5 ml of 20 percent detergent solution and 5 to 6 drops of cupric sulfate solution for each liter of sample. Samples were stored in the dark until analyzed, usually within 2 to 4 weeks. The phytoplankton were counted and enumerated using the Sedwick-Rafter method as described by Slack and others (1973). Zooplankton and net phytoplankton were sampled by towing a number 12-mesh (119-micrometer) net near the water surface.

Benthic invertebrate samples were collected with an Ekman dredge. In most cases three grabs were made at each station and sieved through a U.S. Bureau of Standards Number 30 (589 micrometers) sieve. Invertebrates were usually removed in the field and preserved with 5 percent formaldehyde solution. A few samples that were not easily sieved were preserved with formaldehyde solution and later examined in the laboratory. The invertebrates were counted and expressed as numbers per square meter. Species diversity was computed using the method developed by Wilhm (1970). This diversity index is independent of the number of samples, and it expresses the relative importance of each species.

Primary productivity was measured by means of the oxygen light-and-dark bottle method (American Public Health Association, 1971). Clear and opaque BOD bottles were carefully filled with water from selected depths. The bottles were then suspended in the water at the depth from which the samples were taken and incubated for 24 hours. Dissolved oxygen was determined at the beginning and at the end of the incubation period by the Winkler method except that 0.025 N phenylarsine oxide was used as the titrant instead of sodium thiosulfate. Primary productivity per unit of surface area was calculated by graphical integration of productivity measurements at various depths.

MORPHOLOGY AND HYDROLOGY

Morphology and hydrology have a major influence on the chemical and biological characteristics of lakes and reservoirs. For example, a small lake with a large drainage basin receives more runoff and nutrient input per unit of lake volume than a large lake with comparable drainage and runoff. Consequently, the small lake is more subject to nutrient enrichment (eutrophication) problems. The ratio of drainage area to lake volume is a measure of this morphological characteristic and is useful in understanding lakes and in making comparisons between lakes in the same region.

Numerous other morphological factors also aid in the understanding of lakes. Bortleson and others (1974) used 7 morphological factors, in addition to 4 cultural and 13 water-quality factors in developing a relative classification system to assess the eutrophic potential and condition of lakes in the state of Washington. The 7 morphological factors they used are: (1) mean depth, (2) volume, (3) bottom slope, (4) shoreline configuration, (5) drainage area to volume ratio, (6) altitude, and (7) water renewal time. Except for altitude, these factors are also useful in studying Florida lakes.

Table 2 lists morphologic and hydrologic characteristics for Taylor Creek Impoundment and Blue Cypress Lake. The meaning or derivation of most of these factors is readily apparent; definitions for the few which may not be apparent are as follows:

Bottom slope - slope of the lake bottom is defined as the ratio of the maximum depth to mean lake diameter and is expressed as a percentage.

$$\text{Slope} = \frac{\text{maximum depth} \times \sqrt{\pi} \times 50}{\sqrt{A}}$$

where A = area of the lake

Mean depth - lake volume divided by the surface area.

Shoreline configuration ratio - a measure of geological and littoral processes affecting the shape of the lake and is defined as the ratio of the length of shore to the circumference of a circle having an area equal to that of the lake surface.

$$\text{Ratio} = \frac{\text{length of shoreline}}{2\sqrt{\pi A}}$$

where A = area of the lake

Water renewal time - time required to completely replace the volume of water in the lake with an equal volume of inflowing water.

$$\text{Renewal time} = \frac{\text{Lake volume}}{\text{Annual basin runoff}}$$

The drainage area to Blue Cypress Lake is reported as 489 mi^2, however all runoff from this area probably does not drain directly into the lake. It appears that much of the runoff from the marsh south of State Highway 60 is diverted around the east side of the lake or out of the basin to the Indian River by way of canals. Most inflow to the lake is probably derived from the Blue Cypress Creek basin and Padgett Branch (fig. 1). The actual drainage area contribution directly to lake inflow is estimated to be no more than 200 mi^2.

Table 2.--Morphologic and hydrologic characteristics of Taylor Creek Impoundment and Blue Cypress Lake.

	Taylor Creek Impoundment	Blue Cypress Lake
Drainage area (mi^2)	52	a/ 200
Surface area (acres)	4,000	6,300
Elevation of water surface (1971-75 average) ft	42	22.5
Volume (acre-ft)	26,000	b/ 55,000
Mean depth (ft)	6.5	8.7
Maximum depth (ft)	18	12
Length of shoreline (mi)	21.4	14.3
Shoreline configuration ratio	2.4	1.2
Bottom slope (percent)	0.12	0.06
Drainage area - surface area ratio	8.3	20
Drainage area - volume ratio (ft^2/ft^3)	1.28	2.3
Runoff from drainage basin ($(ft^3/s)/mi^2$)	1.2-1.3	-
Average discharge ft^3/s	c/ 68	-
Water renewal time (yr)	0.5-0.6	b/ 0.4-0.6
Surface area - volume ratio (ft^2/ft^3)	0.15	0.11

a/ Estimated area draining directly into the lake.
b/ Estimate based on drainage area of 200 mi^2 and runoff values ranging from 0.65 to 1.0 $(ft^3/s)/mi^2$.
c/ Estimated.

Comparison of data in table 2 shows several noticeable differences between the two water bodies. Blue Cypress Lake has about four times more drainage area than the impoundment and has a drainage area-volume ratio and a drainage area-surface area ratio twice as large as the impoundment. These factors suggest that Blue Cypress Lake receives considerably more runoff per unit lake volume than does Taylor Creek Impoundment. Both water bodies have about the same water renewal time and on the average water is completely replaced about two times per year. Even though Blue Cypress Lake has 50 percent more surface area than the impoundment, the latter has a considerably longer shoreline (21 mi against 14 mi) and has twice as large a shoreline configuration ratio (2.4 against 1.2). This illustrates the much greater irregularity of the Taylor Creek Impoundment shoreline and indicates that the impoundment has considerably more littoral area and greater nearshore plant-growth capacity.

The SFWMD has measured outflow from the impoundment since July 1971. The average discharge, July 1971-April 1975 (fig. 7), was 135 acre ft (68 ft^3/s) which is equivalent to a runoff of 1.3 $(ft^3/s)/mi^2$ of drainage area. This runoff figure compares favorably with values for nearby Wolf Creek 1.4 $(ft^3/s)/mi^2$ and Jane Green Creek 1.1 $(ft^3/s)/mi^2$. The Wolf Creek basin is about one-half the size of the Taylor Creek basin and the Jane Green Creek basin is about five times larger than the Taylor Creek basin.

The cumulative volume of water discharged from the impoundment from July 1971 to April 1975 is shown in figure 8. Large quantities of water were released during July, August, and September 1974 in response to heavy rainfall. During this 3-month period the volume of water in the impoundment was replaced three times. This rapid flushing is reflected in changes in several water-quality characteristics. These changes are discussed in subsequent sections of this report.

Figure 9 shows monthly lake levels in Blue Cypress Lake and Taylor Creek Impoundment and the monthly rainfall at Melbourne. The figure, in effect, compares stages in a natural impoundment (Blue Cypress Lake) with a controlled or regulated impoundment (Taylor Creek). The level of the impoundment remained relatively stable at 42 ± 1 ft above msl (mean sea level) between mid-1972 and 1975, even though discharges have ranged from 0 to nearly 50,000 acre-ft per month. Blue Cypress Lake, however, has fluctuated from about 19 ft to nearly 25 ft above msl during the same period, responding, in turn, to wet and dry seasons.

STRATIFICATION

Chemical and thermal stratification are two characteristics which clearly distinguish Taylor Creek Impoundment from Blue Cypress Lake and other lakes and streams in the upper St. Johns River basin. Thermal stratification occurs in the impoundment chiefly because of its greater depth, smaller surface area, and poor mixing. The mixing action by wind is minimized by alinement of the levee (L-73) and by trees standing in the impoundment.

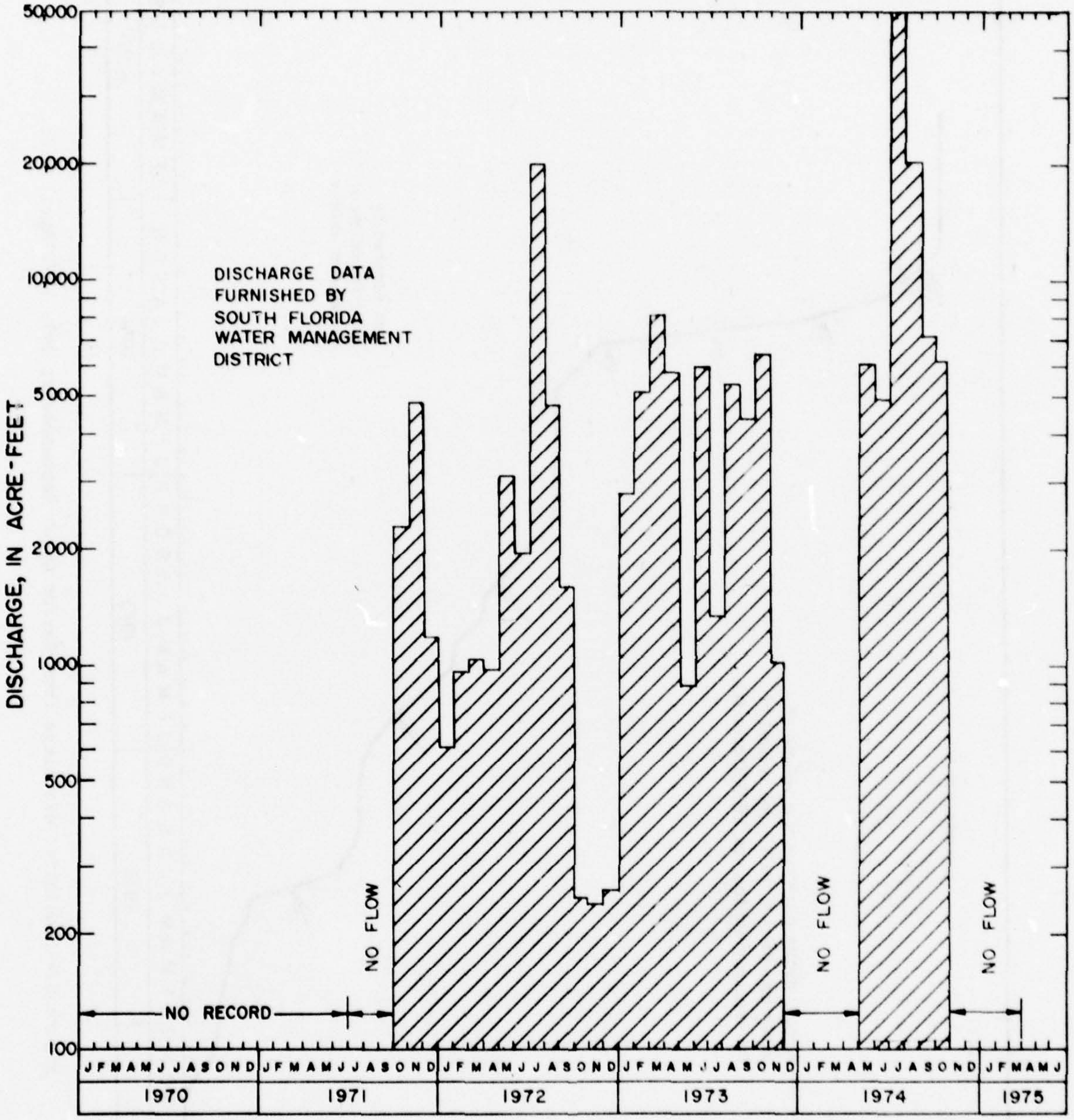

Figure 7.--Mean monthly discharge from Taylor Creek Impoundment at structure 164.

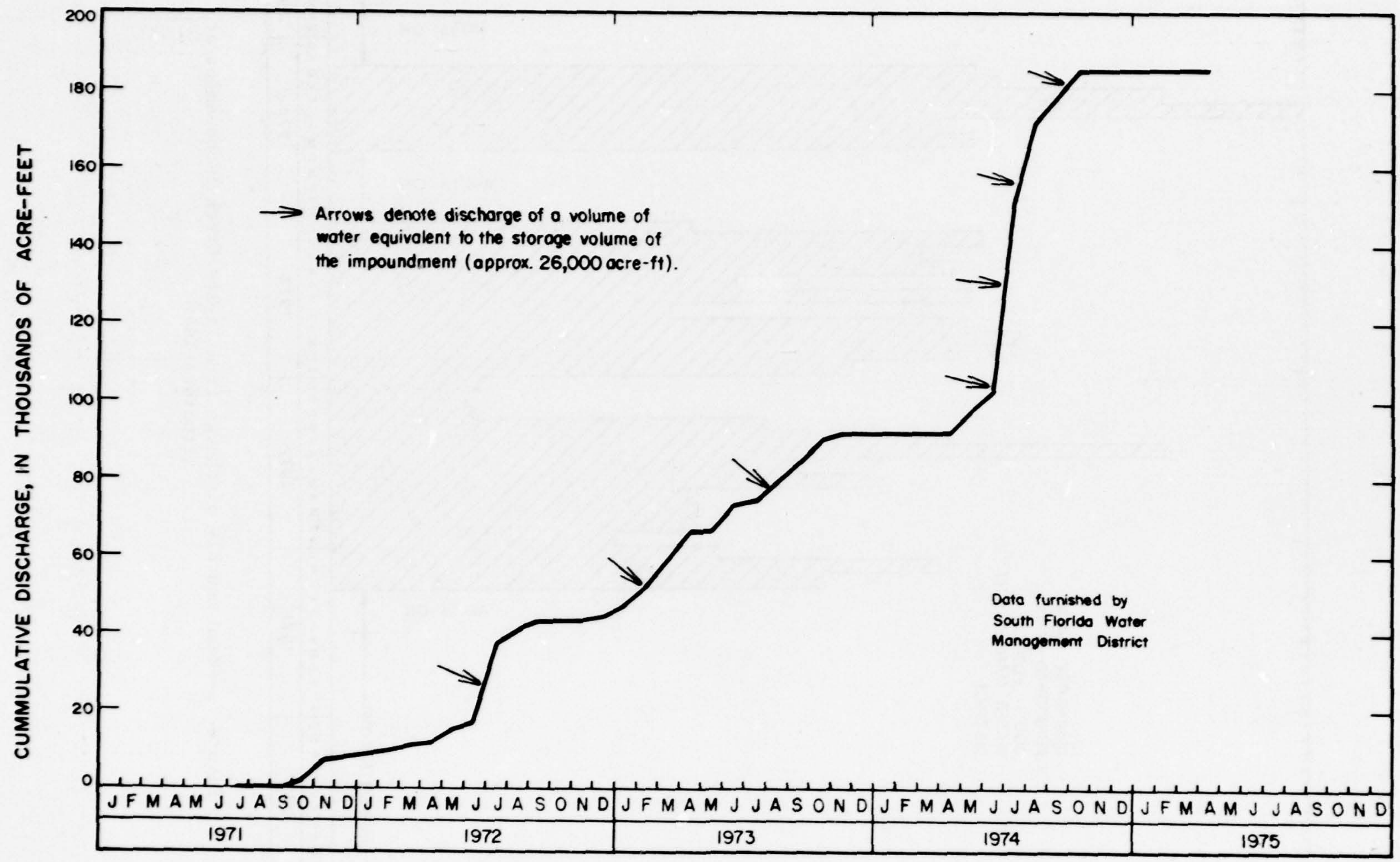

Figure 8.--Cumulative discharge from Taylor Creek Impoundment; July 1972-April 1975.

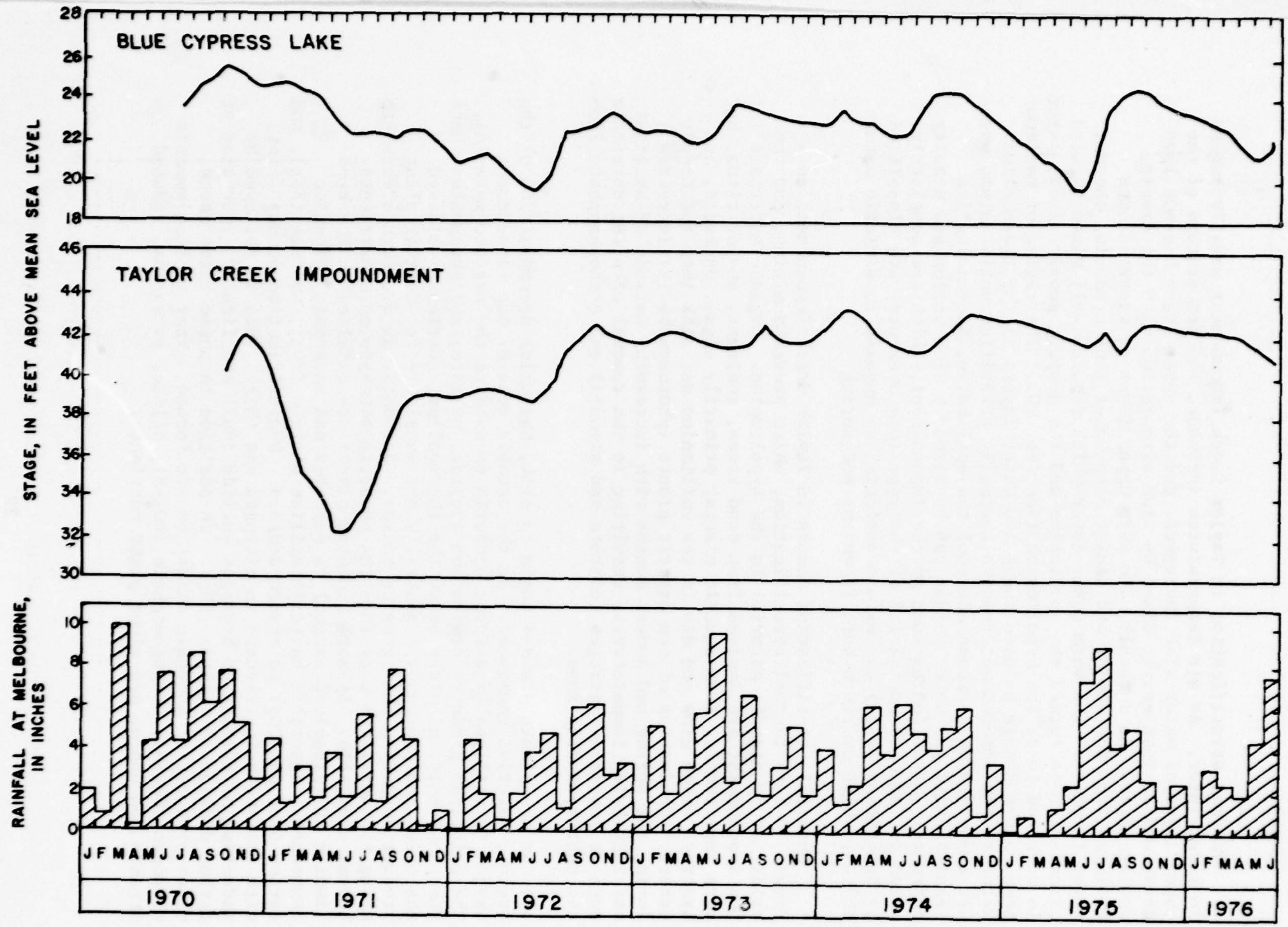

Figure 9.--Lake elevations in Taylor Creek Impoundment and Blue Cypress Lake; mean monthly rainfall at Melbourne.

Thermal stratification in Taylor Creek Impoundment usually begins in late winter. As air temperatures increase, the temperature of the upper layer of water also increases, and the upper layer becomes less dense and is less easily mixed by wind circulation with the deeper, cooler water. As a result, the warm upper layer of water becomes isolated from the cooler and denser deep water thus producing thermal stratification. The warm upper layer which remains well mixed by wind circulation is termed the epilimnion and the deeper, poorly mixed, layer is referred to as the hypolimnion (see fig. 10). The region of maximum temperature change between these two water layers is the thermocline. Water in the impoundment remains thermally stratified until autumn when air temperatures decrease and cool the epilimnion, increasing its density until the water column can be mixed by wind action and density currents. Water bodies such as the impoundment, which are completely mixed during only one period of the year (one overturn) are classified by Hutchinson (1957) as "warm monomictic" as opposed to dimictic water bodies, which overturn both in autumn and spring.

Chemical stratification occurs in Taylor Creek Impoundment as a result of both thermal stratification, which prevents mixing, and the oxidation of organic material in the hypolimnion. Organic materials in the impoundment are derived from dead trees, sediment, and detritus, but more importantly, from aquatic plants, primarily algae, duckweed, and hyacinth which grow and die in the epilimnion and sink into the deeper waters. Production of the aquatic plants (photosynthesis) increases during the spring and summer months with increasing periods of sunlight and increasing temperatures, resulting in the removal of plant nutrients such as inorganic nitrogen (nitrate and ammonia) and orthophosphate from the photosynthetic zone.

As the plants die and begin to sink, bacterial decomposition of the organic material commences. In the aerobic zone of the impoundment oxygen is utilized by aerobic bacteria to oxidize the organic material. The principal products are carbon dioxide, nitrate, and phosphate. Once the plant material sinks below the thermocline, nutrients released in the oxidation process are generally not available for further plant production during that growing season. Not until an overturn occurs--to bring the nutrients back into the euphotic zone--do more nutrients become available. As more and more plants are oxidized in the hypolimnion DO (dissolved oxygen) is depleted and anaerobic oxidation commences. Anaerobic bacteria utilize nitrate (NO_3), sulfate (SO_4), and carbon dioxide (CO_2) as oxygen sources. Denitrification occurs first, with nitrate being reduced to nitrogen gas (N_2). This is followed by reduction of sulfate to hydrogen sulfide (H_2S) and finally, reduction of carbon dioxide to methane (CH_4). In addition to these three gases, other products of anerobic oxidation are formed. They include ammonia nitrogen (NH_3-N), orthophosphate (PO_4-P), silica, potassium, reduced organic compounds, and minor plant nutrients.

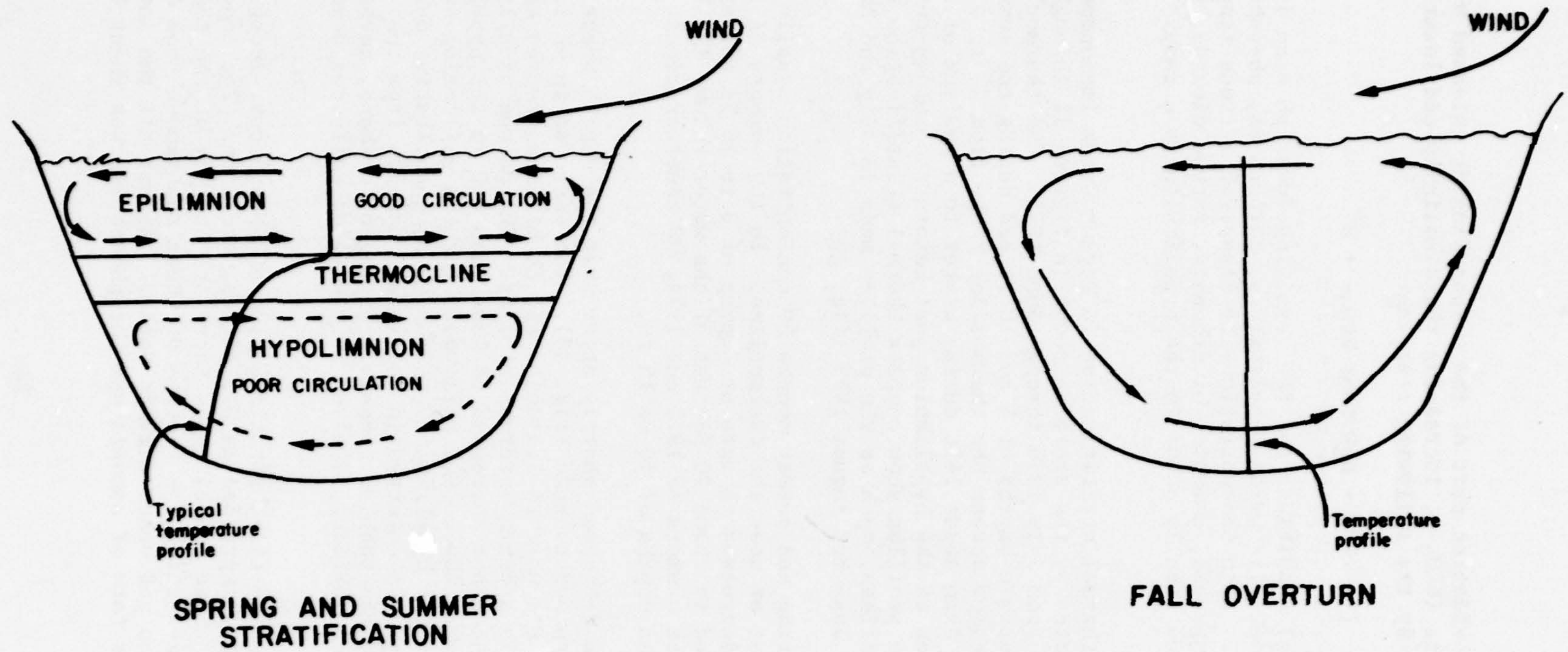

Figure 10.--Diagrammatic section showing classical stratification and circulation patterns for warm monomictic lakes.

In anaerobic oxidation part of the carbon dioxide released hydrolyzes to bicarbonate (HCO_3-), increasing the alkalinity and lowering the pH, as illustrated by the following reaction:

$$(1) \quad CO_2 + H_2O \rightleftharpoons HCO_3- + H^+$$

Anaerobic (reducing) conditions and the resulting lower pH also increases the solubility of metallic oxides, hydroxides, carbonates, phosphates and other minerals. High concentrations of dissolved ferrous iron, orthophosphate, manganese, ammonia, bicarbonate, carbon dioxide, silica, and other substances usually occur in the hypolimnion as a result of this process.

Chemical and thermal stratification in Taylor Creek Impoundment at site 1 are illustrated by the profiles shown in figures 11 through 14 for selected dates from July 1970 through June 1975. The thermocline usually develops between depths of 5 and 10 ft and during the summer temperature differences across the thermocline range from 2° to 6°C. Temperatures range from about 14°C during winter to a maximum of about 26°C near the bottom of the hypolimnion just before the autumn turnover. Several temperature profiles show complex thermal stratification with two or more thermoclines, such as the profiles made in July and August 1972 (fig. 11) and June and August 1973 (fig. 12).

During the spring and summer months DO concentration usually decreases sharply at or near the thermocline. In the summers of 1970-72 DO concentrations decreased to zero at depths of 8 to 10 ft and anaerobic conditions prevailed in about 20 percent of the water volume in the impoundment. In the summers of 1973 and 1974, DO concentrations decreased to zero at depths of 10 to 15 ft.

Both pH and Eh decreased sharply at or near the depths where DO concentrations decreased to zero (fig. 13). The decrease in pH ranged from a few tenths of a unit to 1.5 units and Eh often decreased as much as 400 millivolts in a depth interval of 2 ft. The pH was usually about 6.5 in the equilimnion but decreased to less than 6.0 in the hypolimnion. Typical Eh values were 400 to 600 millivolts for the epilimnion and -200 to 0 millivolts for the hypolimnion. Although no quantitative measurements were made, H_2S was detected in nearly all samples from the anaerobic zone, and gas bubbles (possibly nitrogen, methane, carbon dioxide, or hydrogen sulfide), evolved from samples collected deep in the hypolimnion.

Figure 14 shows vertical stratification of phosphorus, inorganic nitrogen (NO_3+NO_2+NH_3 expressed as N), silica, and iron. The concentrations of all of these constituents increased sharply at the top of the hypolimnion, reflecting the release of these substances from decomposing phytoplankton and other organic matter. Almost all the inorganic nitrogen was in the form of ammonia and the phosphorus was about 65

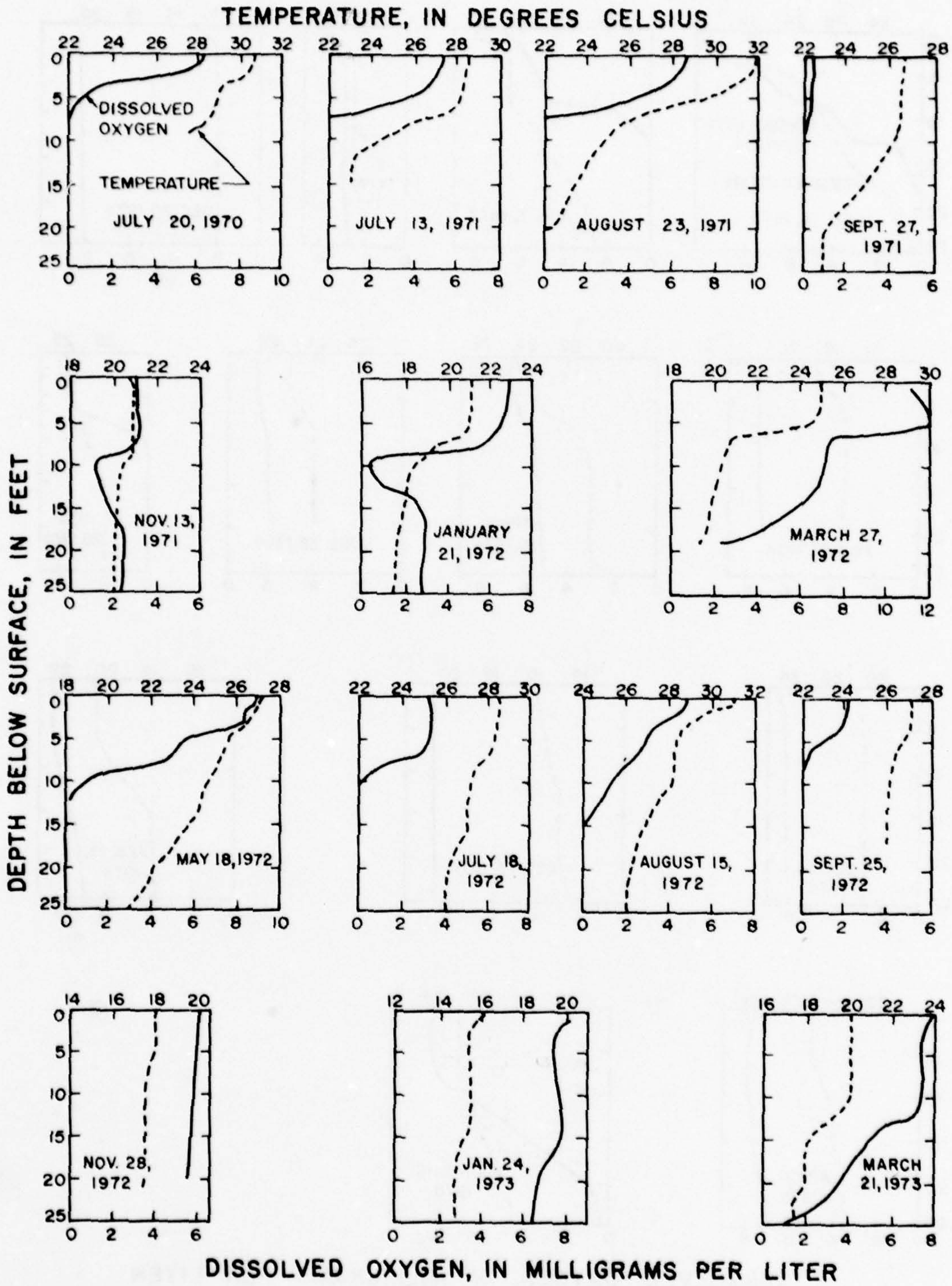

Figure 11.--Profiles of dissolved oxygen and temperature in Taylor Creek Impoundment at Site 1 for July 1970 and selected dates between July 1971 and March 1973.

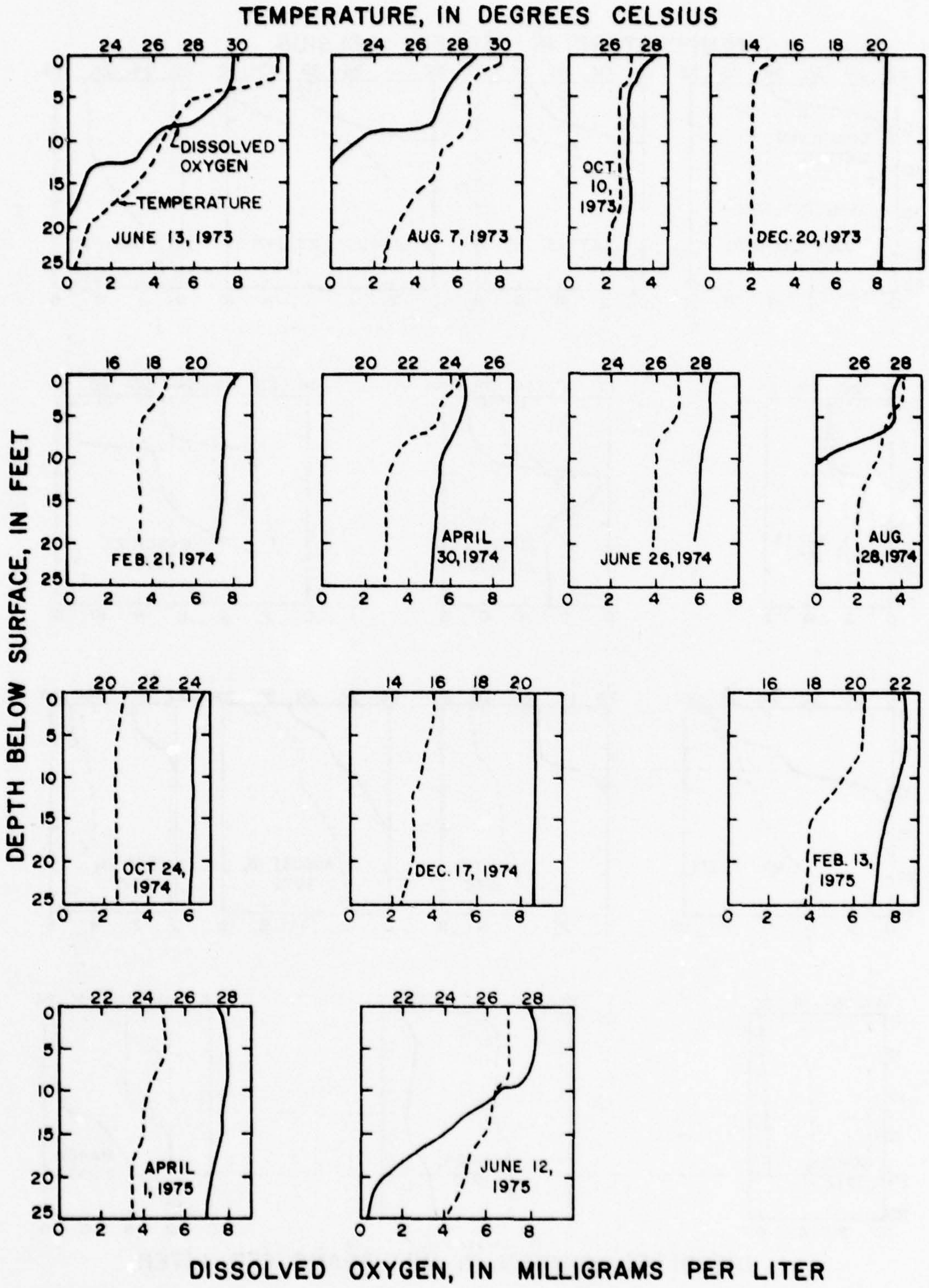

Figure 12.--Profiles of dissolved oxygen and temperature in Taylor Creek Impoundment at Site 1 for July 1970 and selected dates between July 1973 and June 1975.

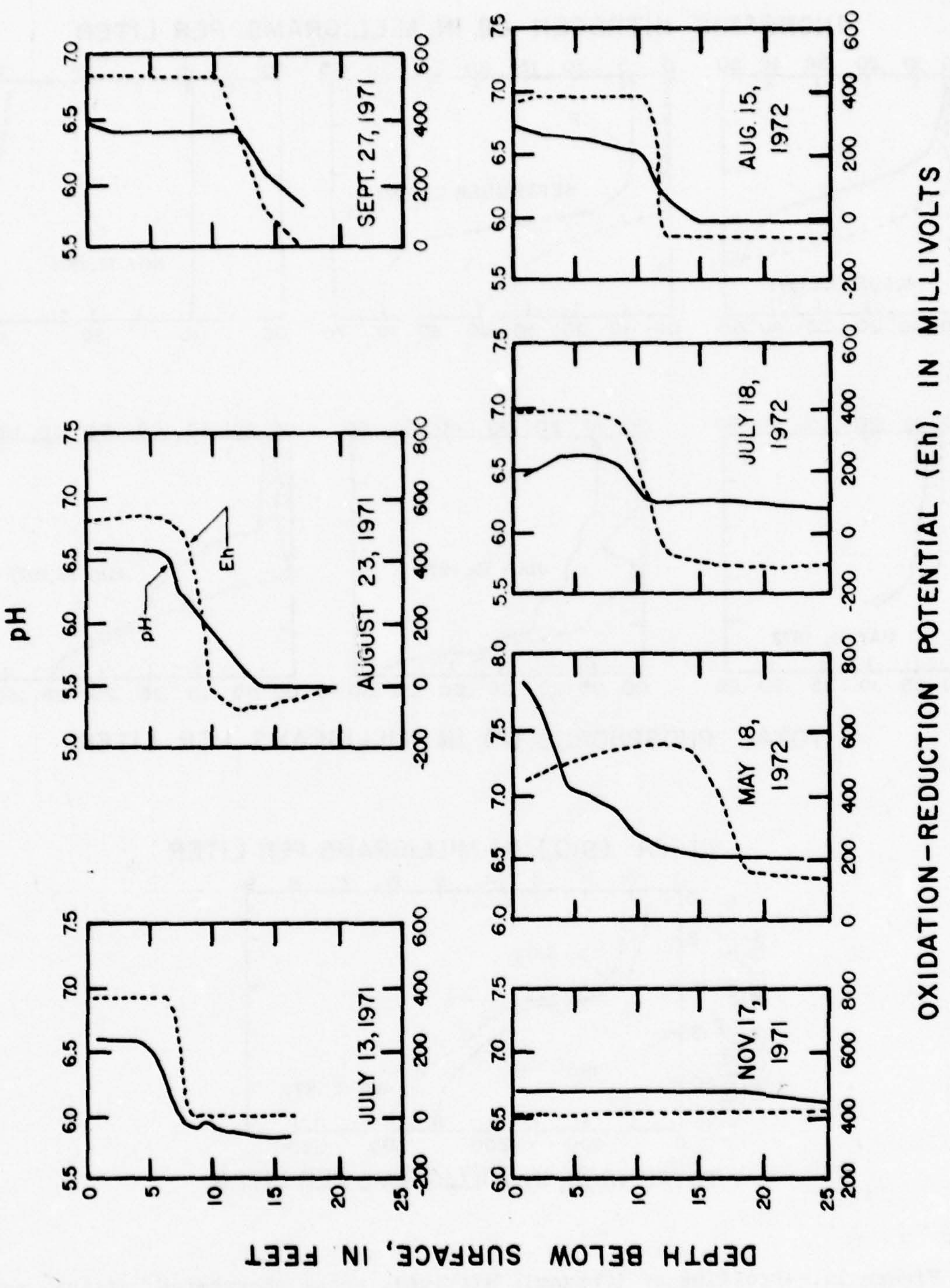

Figure 13.--Profiles of pH and oxidation-reduction potential in Taylor Creek Impoundment at Site 1 for selected dates between July 1971 and August 1972.

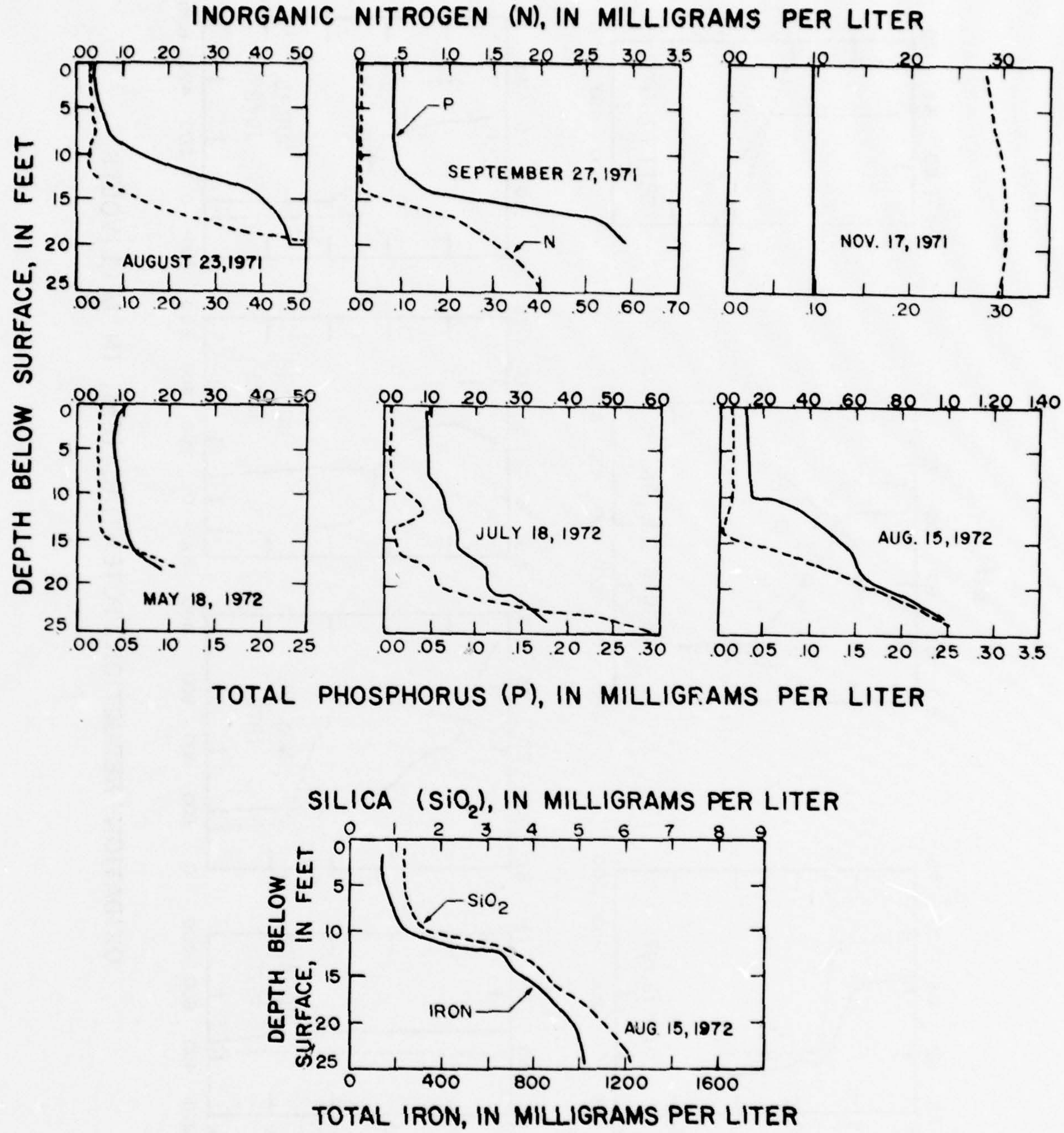

Figure 14.--Profiles of inorganic nitrogen, total phosphorus, silica, and total iron in Taylor Creek Impoundment for selected dates between August 1971 and August 1972.

percent orthophosphate. Iron concentrations were also high in the hypolimnion because of reducing conditions (low Eh) which keeps the iron in the more soluble ferrous (Fe^{+2}) state. When oxygen is present the ferrous iron is oxidized to ferric iron (Fe^{+3}) which is about 1,000 times less soluble. These constituents, and their relation to Eh and pH will be discussed in greater detail in subsequent sections.

Other chemical species and properties are also stratified, including calcium, magnesium, sodium, potassium, chloride, specific conductance, organic carbon, and others. Table 3 gives concentrations of chemical constituents in the surface and bottom waters of the impoundment during periods of nonstratification and maximum stratification. It also gives, for comparison, top and bottom concentrations in Blue Cypress Lake.

In contrast to the impoundment, Blue Cypress Lake exhibits no permanent thermal or chemical stratification, although temporary stratification develops for short periods during hot, calm summer days. The absence of stratification in Blue Cypress Lake is attributed to its shallow depth and the large open surface area, both of which permit winds to keep the lake well mixed. The entire lake can be considered to be an epilimnion. Because the lake is shallow and well mixed, the oxidation and recycling of nutrients should be more rapid than in Taylor Creek Impoundment.

WATER CHEMISTRY

The water chemistry of Taylor Creek Impoundment is governed by many factors. These include inflow of inorganic and organic solutes leached from the surrounding drainage basin, inflow of suspended sediment and detritus, input of solutes and aerosols from rainfall and dry fallout, chemical reactions and biological activity in the impoundment, water-sediment interactions and seasonal stratification in the impoundment. The following sections discuss the water chemistry in the impoundment in relation to some of these controlling factors and also, to observed changes in water chemistry with time. Discussion of Blue Cypress Lake is included for comparison.

Dissolved Oxygen

DO concentrations in the upper few feet of the impoundment (site 1) often varied between 2 to 4 mg/L daily and from less than 1 mg/L to more than 8 mg/L seasonally (table 4; fig. 15).

DO concentrations near the surface were lowest during the early stages of the autumn turnover when the anaerobic hypolimnion mixed with the epilimnion. Also, during the turnover, concentrations were higher in the shallow littoral areas than in the near surface waters of the deeper areas. For example, on September 27, 1971 the surface DO concentrations in early afternoon were 4.6 mg/L at site 3, 1.6 mg/L at site 2, and 0.5 mg/L at site 1 (fig. 15).

Table 3.--Chemical Composition of Taylor Creek Impoundment at site 1 during stratified and nonstratified periods. (Blue Cypress Lake shown for comparison; results in milligrams per liter except where indicated.)

	TAYLOR CREEK IMPOUNDMENT						BLUE CYPRESS LAKE	
	July, 1971 Stratified		November, 1971 Non-Stratified		July, 1972 Stratified		July 1971 Non-Stratified	July 1971
PARAMETER	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM
TEMPERATURE (°C)	29.0	24.0	20.8	20.0	28.5	26.0	29.0	28.0
Dissolved oxygen	4.8	.0	3.1	2.2	3.1	.0	4.9	4.4
pH (units)	6.6	5.85	6.7	6.6	6.5	6.2	7.1	7.2
Redox potential (mv)	+380	0	+410	+420	+380	-100	+515	+515
5-day BOD	3.8	1.1	.9	.9	1.6	.9	1.2[a]	-
Nitrate-nitrogen	.02	.00	.02	.02	.00	.00	.20	.20
Ammonia-nitrogen	.04	.02	.25	.26	.02	.59	.14	.07
Organic-N	1.5	1.6	1.0	1.6	1.1	1.2	1.0[a]	-
Orthophosphate (P)	.013	.192	0.059	0.065	.025	1.50	.036	.039
Total phosphorus (P)	.036	.215	.088	.095	.037	.18	.055	.062
Bicarbonate (HCO_3)	30	41	32	30	27	37	46[a]	-
Carbon dioxide (CO_2)	12	95	10	12	11	28	5.8	4.6
Specific Conductance (umhos/cm)	125	140	118	118	102	128	260	263
Dissolved solids	98	113	78	82	-	-	205[a]	-
Dissolved iron (Fe)	.10	1.60	.18	.19	.08	.86	.12[a]	-
Silica (SiO_2)	1.2	2.9	2.7	2.7	1.3	3.2	8.5	9.5
Calcium (Ca)	9.6	12	8.8	9.0	-	-	21[a]	-
Organic carbon	24	31	18	17	19	24	24[a]	-

[a]Depth integrated.

Table 4.— Diel oxygen measurements at about a foot below the water surface in Taylor Creek Impoundment (site 1) and Blue Cypress Lake (site 17).

TAYLOR CREEK IMPOUNDMENT

Oct. 20-21, 1969	Jan. 26-27, 1970		Apr. 27-28, 1970		July 20-21, 1970		July 12-13, 1971		Mar. 27-28, 1972		May 17-18, 1972	
	Time	DO (mg/L)	Time	DO (mg/L)	Time	DO (mg/L)	Time	DO (mg/L)	Time	DO (mg/L)	Time	DO (mg/L)
DO less than 0.4 mg/L from 1500 hours on Oct. 20 to 0800 hours on Oct. 21.	1130	8.5	1200	4.0	1200	5.5	1900	8.2	1800	7.9	0900	6.6
	1200	9.4	1400	4.2	1400	5.6	2100	7.6	2000	6.6	1100	7.4
	1400	9.0	1600	4.6	1600	6.5	2300	6.5	2200	6.0	1300	8.0
	1500	8.6	1800	4.4	1700	7.0	0100	5.2	2400	6.0	1500	8.4
	1600	10.2	1900	3.6	1900	5.5	0300	5.4	0200	5.5	1700	8.1
	1700	10.8	2000	3.2	2100	5.0	0500	4.8	0400	4.6	1900	7.6
	1900	8.8	2200	3.5	2300	5.0	0700	5.1	0600	4.7	2000	7.4
	2100	7.6	1400	3.8	0100	4.4	0830	5.3	0800	4.8	1300	8.2
	2100	7.2	0200	4.0	0300	4.3			1000	6.0	1415	8.2
	0100	7.2	0400	4.0	0500	4.2			1200	6.9		
	0300	7.6	0600	4.4	0700	4.4			1400	8.4		
	0500	7.2	0800	4.1	0900	5.0			1600	7.8		
	0700	6.2										
	0900	6.3										

BLUE CYPRESS LAKE

Oct. 21-22, 1969		Jan. 27-28, 1970		Apr. 29-30, 1970		July 22-23, 1970		Aug. 16-17, 1972	
Time	DO (mg/L)	Time	DO (mg/L)	Time	DO (mg/L)	Time	DO (mg/L)	Time	DO (mg/L)
1700	4.8	1300	8.0	0900	7.1	0900	7.2	1600	5.0
2000	4.2	1500	7.9	1300	7.2	1100	9.6	1800	5.3
2400	4.1	1800	7.8	1600	7.1	1400	12.0	2000	5.5
0300	4.0	2100	7.7	1800	8.1	1600	12.8	2200	5.2
0600	3.1	2400	7.6	2100	7.2	1800	14.4	2400	5.3
0800	4.2	0300	7.5	0100	7.7	0600	7.2	0200	5.1
		0600	7.3	0500	7.1	1000	8.8	0400	4.8
		0900	7.6	0900	7.0			0600	4.9
		1200	7.9					0800	5.1
								1000	5.4
								1200	6.0
								1400	6.7
								1600	6.4

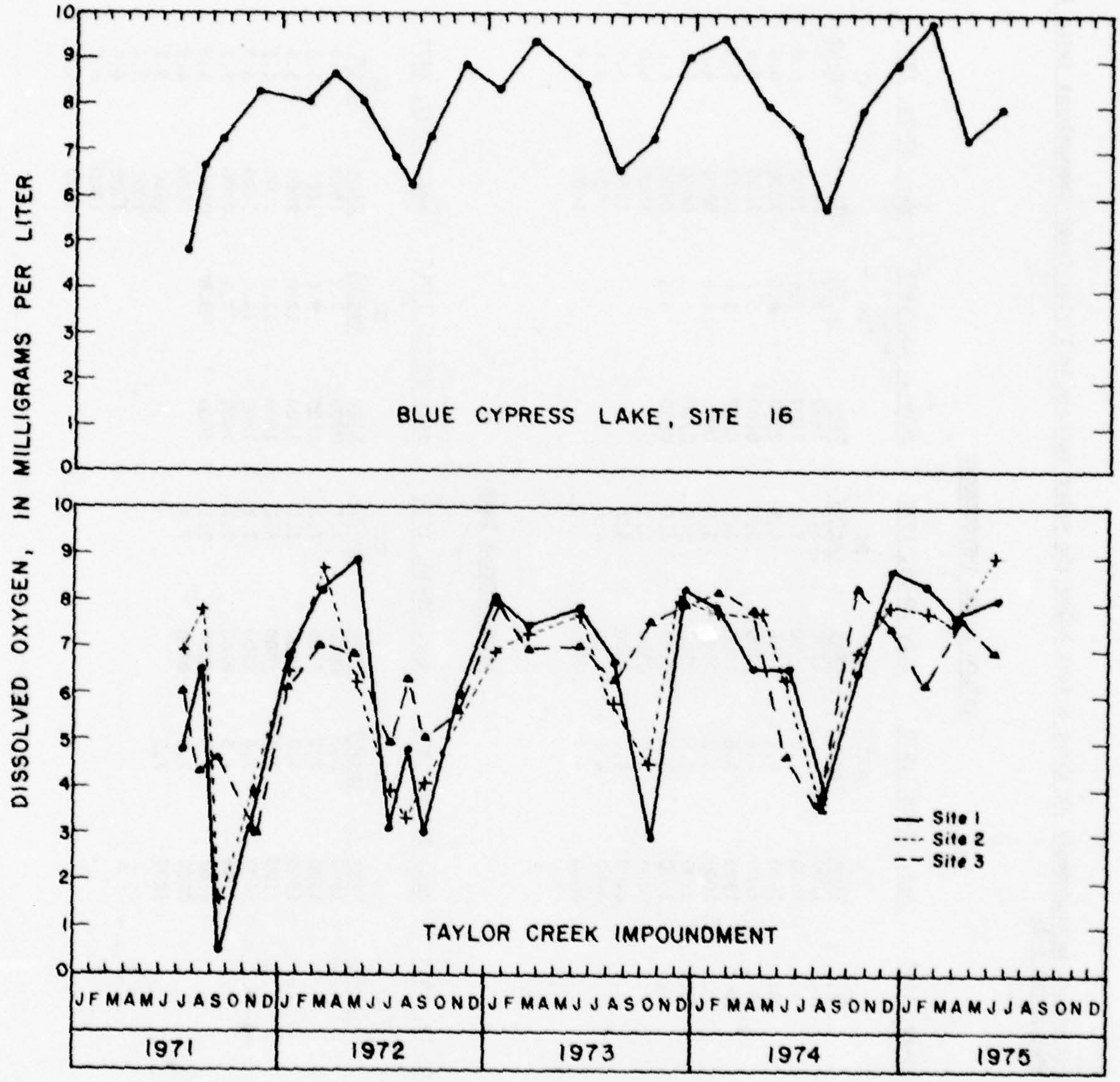

Figure 15.--Generalized seasonal variations in dissolved oxygen concentrations in Taylor Creek Impoundment and Blue Cypress Lake.

In general, the concentration of DO in the deep water of the impoundment has increased between 1970 and 1975 (fig. 16). The depth to the top of the anaerobic zone became greater each year from 1970 through 1973 and the length of time during which the hypolimnion was anaerobic decreased. In 1971 the minimum depth at which water was anaerobic was about 7 feet and anaerobic conditions prevailed from early March until early November. In 1974 the minimum depth at which water was anaerobic was 12 ft and anaerobic conditions prevailed for less than 2 months in August and September. The improvement in DO probably is the result of a stabilization of biological conditions in the impoundment and may be largely due to the flushing of organic material and nutrients from the inundated land. Changes in other parameters including nitrogen, phosphorus, and major ions decreased as DO increased. These will be discussed in later sections.

DO concentrations in Blue Cypress Lake were less variable than in the impoundment. DO generally varied less than 2 mg/L daily (table 4, fig. 15). The variations may become greater during heavy algal blooms. During a large bloom of the blue-green algae Anabaena sp. in July 1970, DO concentrations ranged from near 7 mg/L to more than 14 mg/L over a 24-hour period. However, only one such bloom was observed between 1969 and 1975. Seasonally, DO concentrations ranged from 5 to 10 mg/L and the water was generally more than 80 percent saturated with oxygen (fig. 15). DO concentrations were usually uniform throughout the lake.

Nutrients

Nutrients are chemical compounds or elements essential for the reproduction and growth of algae. At least 21 elements in some chemical combination are known to be essential for algal growth (Greeson, 1971). Of these 21, nitrogen and phosphorus are generally considered to be the ones which most often limit algal growth. Excessive concentrations of these two nutrients can stimulate nuisance algal blooms and increase the rate of eutrophication of water bodies. Silicon is a key nutrient which can be a limiting factor in diatom production. Also, when phosphorus is plentiful in lakes and diatom production is limited by depletion of silica, blooms of blue-green algae commonly result (Russel-Hunter, 1970).

Nitrogen normally occurs in four forms in the aquatic environment. These are organic nitrogen (proteins, amino acids, polypeptides, and others), ammonia (NH_3-N), nitrite (NO_2-N) and nitrate (NO_3-N). Phosphorus occurs as soluble inorganic orthophosphate (PO_4-P) and as dissolved and particulate organic phosphorus. The forms of nitrogen and phosphorus most readily assimilated by plants are nitrate, ammonia, and orthophosphate. Dissolved silica occurs in natural waters primarily as silicic acid (H_4SiO_4). Concentrations of silica are reported as the oxide (SiO_2).

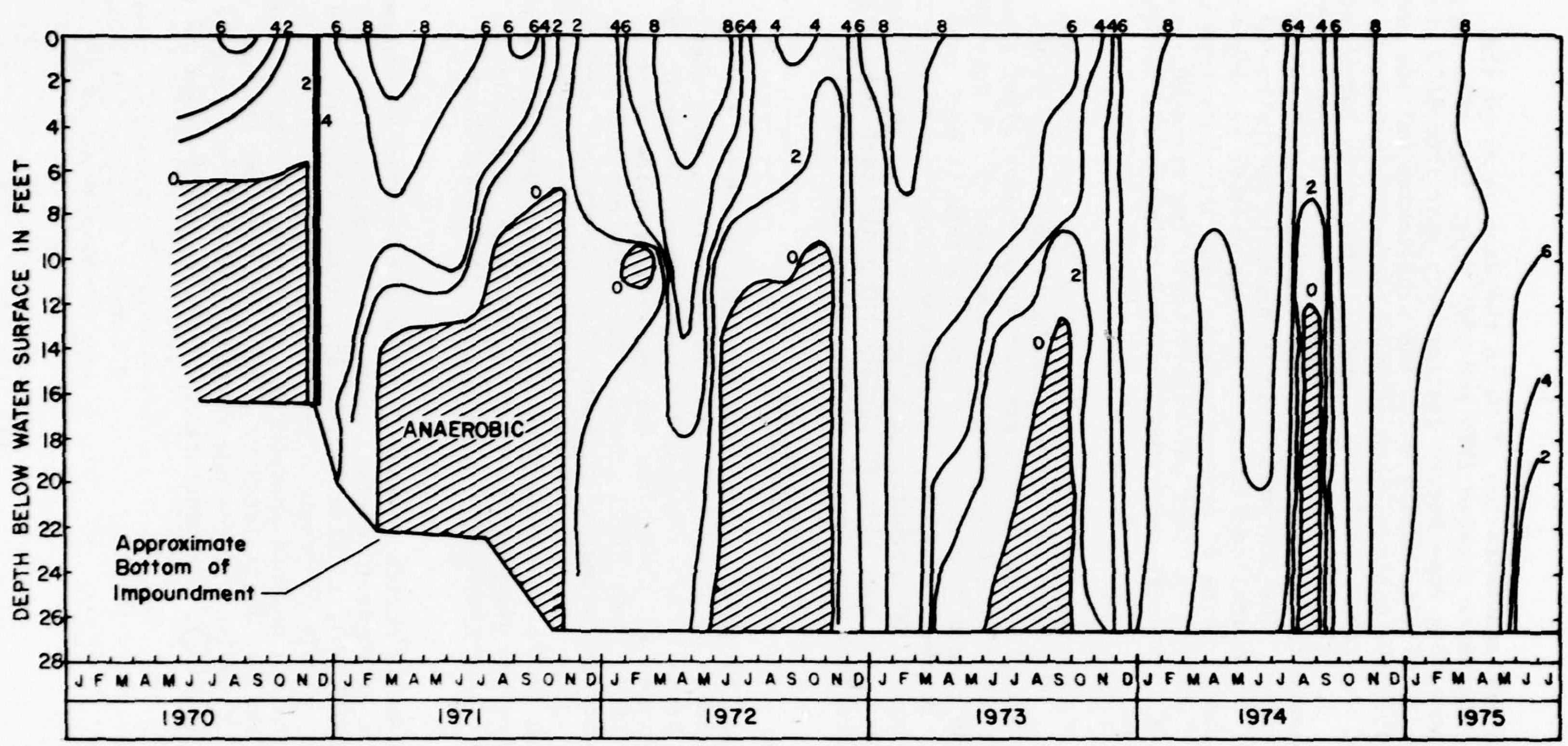

Figure 16.--Dissolved oxygen concentration in Taylor Creek Impoundment shown as a function of depth and time.

A statistical summary of nitrogen, phosphorus, and silica data is given in table 5. The total organic nitrogen concentration averaged 1.05 mg/L at site 1 in the impoundment and 0.98 mg/L at site 3. Concentrations were slightly higher in Blue Cypress Lake, averaging 1.25 mg/L. In both water bodies 85 to 90 percent of the nitrogen was organic. Inorganic nitrogen, mostly ammonia, averaged 0.223 mg/L at site 1 in the impoundment and 0.066 mg/L at site 3. In Blue Cypress Lake, nitrate was the major inorganic species, averaging 0.088 mg/L; ammonia averaged 0.066 mg/L. Total phosphorus concentrations were highest at site 1 in the impoundment (average 0.105 mg/L), chiefly because of stratification. At site 3 average total phosphorus concentrations were much lower (average 0.046 mg/L) and were similar to average concentrations in Blue Cypress Lake (0.053 mg/L). From 60 to 75 percent of the phosphorus was soluble inorganic orthophosphate.

For comparison, the average total organic nitrogen concentration in the St. Johns River at the outlet of Lake Poinsett was 1.33 mg/L and total phosphorus averaged 0.061 mg/L; total organic nitrogen and total phosphorus averaged 0.76 and 0.085 mg/L respectively in nearby Wolf Creek and 1.09 and 0.053 respectively in Jane Green Creek. According to Davis and Marshall (1975) and Joyner (1974), total organic nitrogen and total phosphorus concentrations in Lake Okeechobee averaged 1.44 and 0.051 mg/L, respectively, during the period 1969-73. The average total organic nitrogen and total phosphorus concentrations of 55 central Florida lakes studied by Brezonik and Shannon (1971) were 1.02 and 0.125 mg/L respectively. These comparative data indicate that, except for phosphorus in the deep waters of the impoundment, nitrogen and phosphorus concentrations in the impoundment and Blue Cypress Lake are within the range observed in other water bodies in central and southern Florida.

Silica concentrations averaged 2.6 mg/L in the impoundment and 4.1 mg/L in Blue Cypress Lake. Silica averaged about 4.0 mg/L at the outlet of Lake Poinsett and in Jane Green Creek, 6.2 mg/L in Wolf Creek and 5.2 mg/L in Lake Okeechobee.

Stratification is the dominant factor affecting seasonal variations in nitrogen and phosphorus in the impoundment (fig. 17, 18). Concentrations in the bottom waters gradually build up during spring and summer, then rapidly decrease when the autumn turnover occurs (fig. 17).

A long-term decrease in total phosphorus concentration has occurred at site 1 (fig. 17). In 1970, after the initial filling of the impoundment and in 1971, phosphorus concentrations ranged from 0.05 to 0.1 mg/L in the epilimnion, but since 1971 phosphorus concentrations have generally been less than 0.05 mg/L. Phosphorus concentrations in the hypolimnion have decreased dramatically since 1972. Better indication of the long-term decrease in phosphorus is its concentration after the fall turnover when the impoundment is well-mixed. Phosphorus decreased to about 0.09 mg/L after the turnover in 1969 and 1970, and to 0.04 mg/L after the turnover in 1974. The decrease has probably resulted from the

Table 5.--Statistical summary of data on nitrogen, phosphorus and silica in Taylor Creek Impoundment and Blue Cypress Lake. (Results in milligrams per liter; includes all sampling depths. All data are from point samples).

Parameter	Number of Values	Min.	Max.	Mean	Standard Deviation
Taylor Creek Impoundment (All Sites)					
Nitrate (N)	225	0.00	0.12	0.011	0.025
Nitrite (N)	225	.00	.03	.010	.005
Ammonia (N)	225	.00	3.6	.150	.377
Organic nitrogen (N)	154	.27	2.8	1.05	.48
Orthophosphate (P)	232	.007	.52	.063	.086
Total Phosphorus (P)	216	.01	.65	.088	.095
Silica (SiO_2)	218	.2	7.6	2.63	1.7
Taylor Creek Impoundment (Site 1)					
Nitrate (N)	139	0.00	0.10	0.009	0.022
Nitrite (N)	139	.00	.03	.011	.005
Ammonia (N)	139	.00	.36	.203	.470
Organic Nitrogen (N)	83	.27	2.6	1.05	.51
Orthophosphate (P)	146	.007	.52	.077	.103
Total Phosphorus (P)	137	.02	.65	.105	.114
Silica (SiO_2)	133	.2	7.6	2.8	1.7
Taylor Creek Impoundment (Site 2)					
Nitrate (N)	16	0.00	0.02	0.001	0.005
Nitrite (N)	16	.00	.01	.006	.004
Ammonia (N)	16	.00	.31	.067	.076
Organic Nitrogen (N)	16	.69	2.8	1.41	.57
Orthophosphate (P)	16	.01	.06	.029	.017
Total Phosphorus (P)	16	.04	.10	.055	.019
Silica (SiO_2)	16	0.3	2.7	1.5	0.8
Taylor Creek Impoundment (Site 3)					
Nitrate (N)	26	0.00	0.08	0.014	0.026
Nitrite (N)	26	.00	.02	.010	.005
Ammonia (N)	26	.00	.21	.042	.043
Organic Nitrogen (N)	26	.27	2.2	.98	.42
Orthophosphate (P)	26	.008	.05	.029	.012
Total Phosphorus (P)	26	.021	.08	.046	.017
Silica (SiO_2)	25	.3	5.7	2.5	1.7
Blue Cypress Lake (All Sites)					
Nitrate (N)	59	0.00	0.37	0.088	0.091
Nitrite (N)	59	.00	.03	.009	.006
Ammonia (N)	59	.00	.85	.066	.114
Organic Nitrogen (N)	51	.54	3.40	1.25	.52
Orthophosphate (P)	57	.01	.10	.036	.019
Total Phosphorus (P)	56	.01	.12	.053	.019
Silica (SiO_2)	53	.0	12	4.1	3.0
Blue Cypress Lake (Site 16)					
Nitrate (N)	49	.00	.37	.089	.095
Nitrite (N)	49	.00	.03	.010	.006
Ammonia (N)	49	.00	.85	.064	.123
Organic Nitrogen (N)	41	.54	3.0	1.19	.45
Orthophosphate (P)	47	.01	.10	.037	.020
Total Phosphorus (P)	46	.01	.12	.055	.020
Silica (SiO_2)	43	.0	12	4.0	3.1

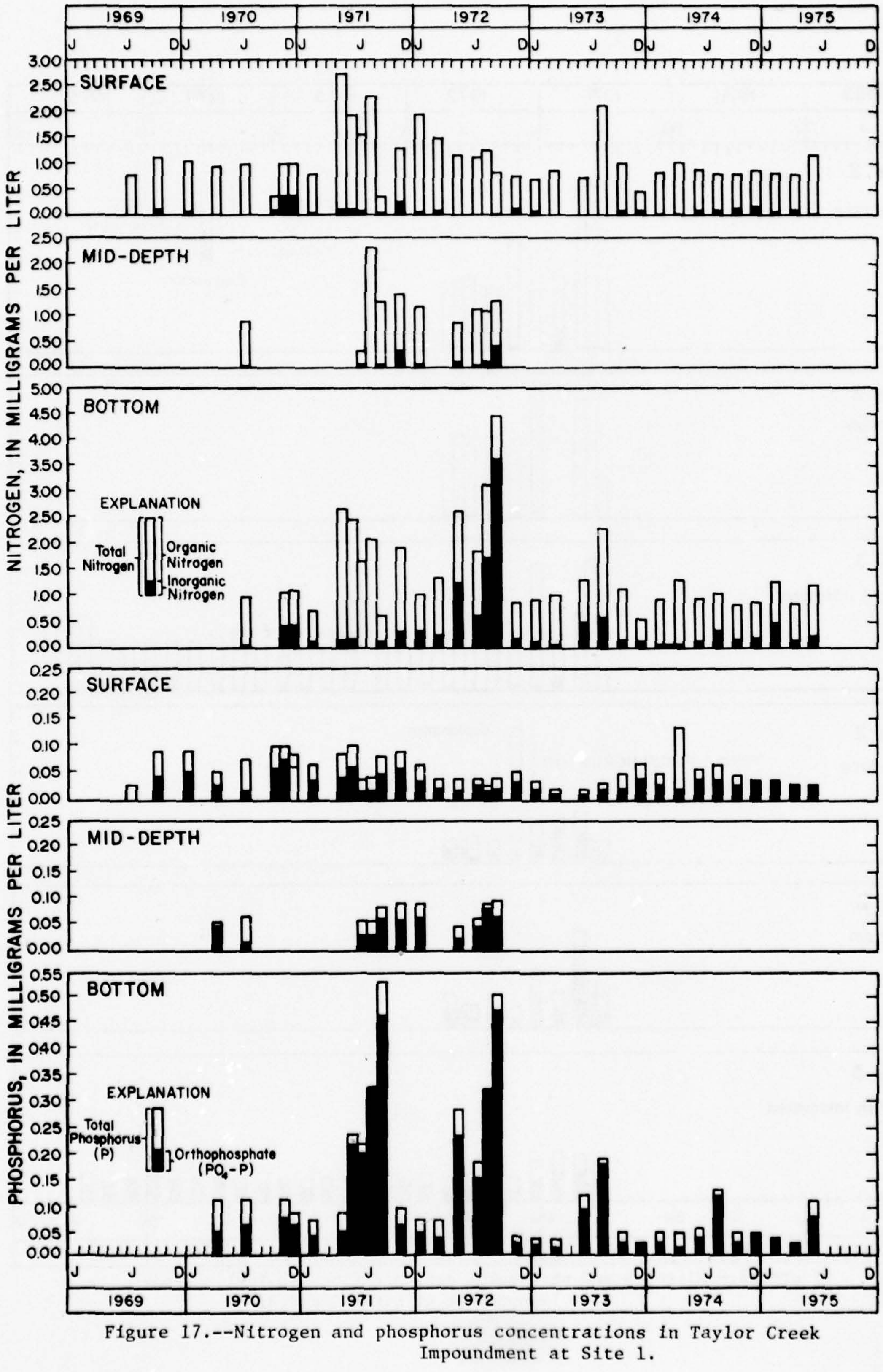

Figure 17.--Nitrogen and phosphorus concentrations in Taylor Creek Impoundment at Site 1.

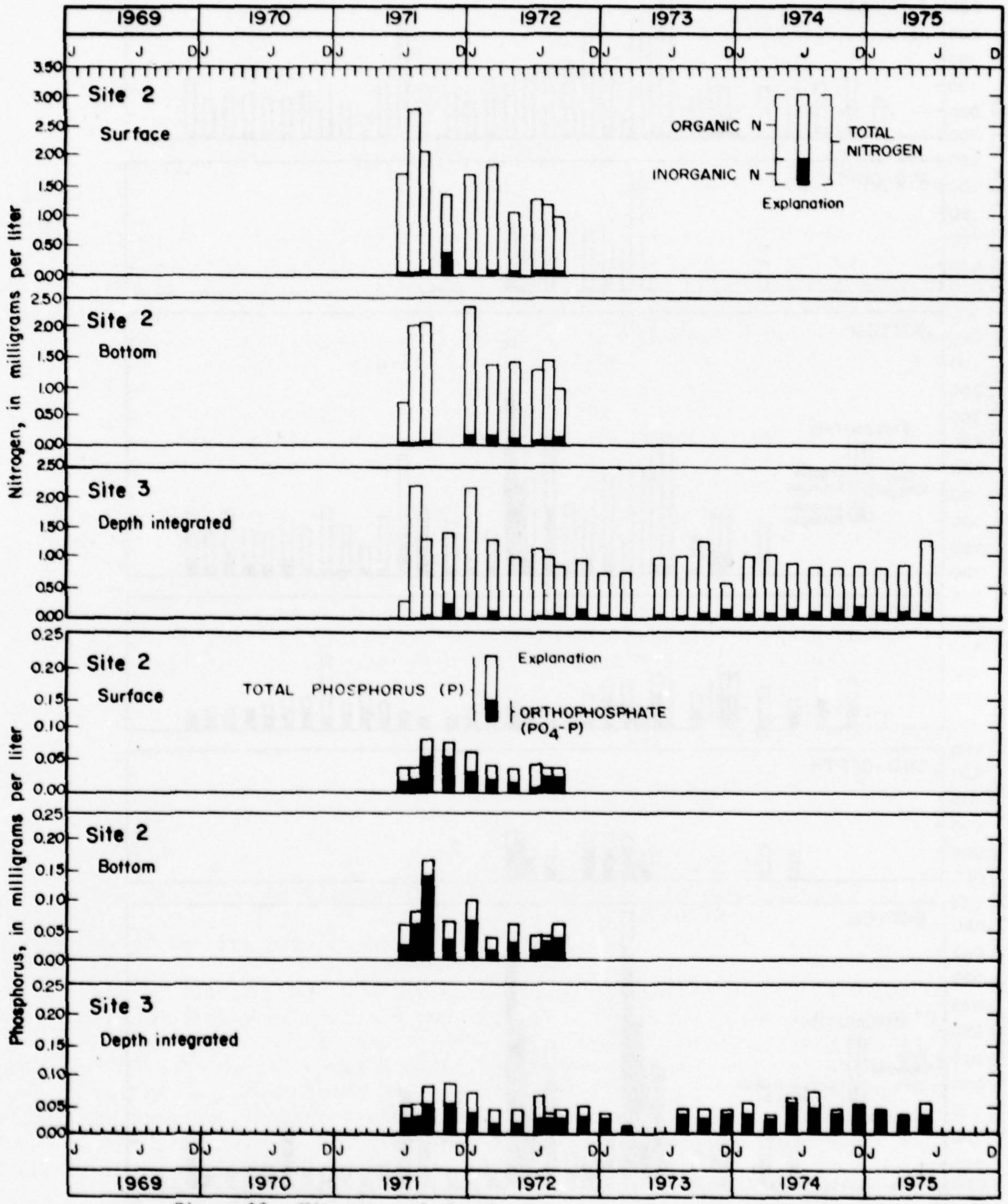

Figure 18.--Nitrogen and phosphorus concentrations in Taylor Creek Impoundment at Sites 2 and 3.

flushing of phosphorus and other material leached from the inundated vegetation and soils.

In 1975 total nitrogen concentration at site 1 in the impoundment was approximately 1 mg/L, about the same as during 1969 and 1970. The total nitrogen concentration in the surface and bottom waters was considerably higher than 1 mg/L in 1971 and 1972 probably because of greater primary production during that period.

In Blue Cypress Lake, phosphorus concentrations appear to be lowest in the spring and early summer and highest in autumn, however no long-term trends are apparent (fig. 19). No seasonal or long-term trends were observed for nitrogen. Because the lake does not stratify, nitrogen and phosphorus variations result mainly from changes in biological activity, rates of input and output, and climatic conditions.

During stratification inorganic nitrogen and phosphorus concentrations in the epilimnion of the impoundment are reduced to a few hundredths of a mg/L by algal assimilation. In the hypolimnion, algal decomposition releases these nutrients, and concentrations of both ammonia and orthophosphate increase. High concentrations of ammonia and orthophosphate in the anaerobic bottom waters may also be partly due to the release of these compounds from bottom sediments. Mortimer (1971) reported that if the DO concentration at the water-sediment interface is less than 2 mg/L, large quantities of ammonia, orthophosphate, silica, iron, and other substances are released. On the other hand, if DO is greater than 2 mg/L, very little of these substances is released.

Stumm and Morgan (1970) give the following equation for the assimilation and release of nitrogen and phosphorus by algae:

$$106CO_2 + 16NO_3^- + HPO_4^{-2} + 122H_2O + 18H^+ + \text{trace elements}$$

$$+ \text{ energy} \underset{\text{Respiration}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} \underset{\text{(algal protoplasm)}}{C_{106}H_{263}O_{110}N_{16}P} + 138O_2 \qquad (2)$$

As shown by the equation, nitrogen and phosphorus are assimilated and released in a molar ratio of 16 to 1. When either of these elements is depleted photosynthesis ceases. In Taylor Creek Impoundment during stratification, the molar ratio of inorganic nitrogen to phosphorus in the epilimnion is occasionally reduced to less than 3, with inorganic nitrogen being virtually depleted. This suggests that nitrogen rather than phosphorus may be a limiting nutrient for plant growth in the impoundment. The inorganic-nitrogen-to-phosphorus molar ratio in the hypolimnion, where decomposition and nutrient release occurs, ranges from 7 to 12 and the ratio at the time of the fall overturn reaches a maximum of 10 to 14.

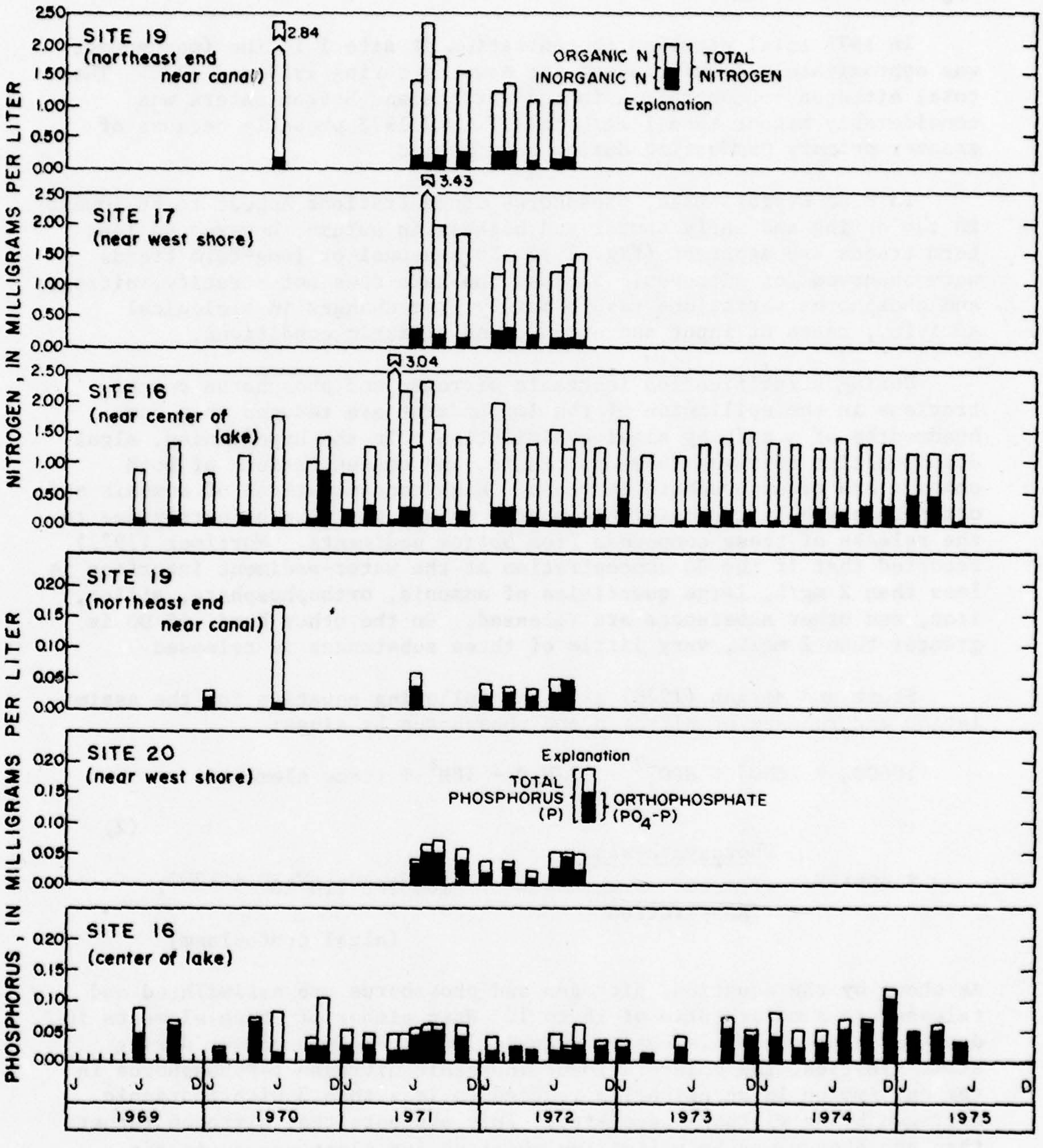

Figure 19.--Nitrogen and phosphorus concentrations in Blue Cypress Lake.

The above equation also serves to illustrate the relation between phosphorus and oxygen in photosynthesis and respiratory processes. Each milligram of phosphorus (0.03 millimole) converted into algal protoplasm by photosynthesis produces about 100 milligrams of algal biomass and yields about 140 milligrams of oxygen. Conversely, when the 100 milligrams of algal biomass dies and sinks into deep water such as the hypolimnion of Taylor Creek Impoundment, 140 milligrams of oxygen are required for its complete decomposition. From this relation it is easy to see why the impoundment, which has a relatively small hypolimnion by volume, can easily develop anaerobic conditions.

Silica concentrations in both the impoundment and Blue Cypress Lake exhibit dramatic seasonal variations. In the surface waters (1 to 3 ft depth) of the impoundment, silica concentrations vary from near zero to more than 6 mg/L, and in the hypolimnion during stratification the concentrations can exceed 6 mg/L (fig. 20). In Blue Cypress Lake silica concentrations in integrated samples range from near zero to more than 10 mg/L. Seasonally, concentrations are usually lowest during spring and summer and highest in autumn; concentrations can change an order of magnitude in 2 or 3 months (fig. 20).

The large variations in silica are evidently caused by the assimilation and release of this element by diatoms. Lund (1965) reported that various species of diatoms contained 26 to 63 percent silica on a dry weight basis. Lund (1969) also reported that the diatom Asterionella formosa utilizes silica and phosphorus in a ratio of more than 2,000 to 1, which further suggests that large variations in silica concentrations can occur as a result of diatom growth. Relations were observed between silica concentrations and diatoms in the impoundment and Blue Cypress Lake. These are discussed in the section on phytoplankton.

Organic Material

During the study, three indicators of organic material were measured: TOC (total organic carbon), BOD (5-day biochemical oxygen demand), and water color. TOC is a measure of the total amount of organic carbon in the water regardless of the compounds or their biodegradability. BOD is a measure of the amount of oxygen utilized in the bacterial oxidation of organic matter, however, it does not provide a good measure of slowly degradable natural organic substances such as humic and fulvic acids which are leached from soils and vegetation. Water color is simply a measure of the yellow-brown coloration of water caused by dissolved and colloidal organic compounds. All three of these measurements are useful in assessing the organic content of natural waters.

TOC averaged 18 mg/L in Taylor Creek Impoundment (table 6) and about 22 mg/L in Blue Cypress Lake. As a rule-of-thumb, TOC values can be multiplied by a factor of 2 to obtain an estimate of the concentration of organic material. The foregoing values indicate an average

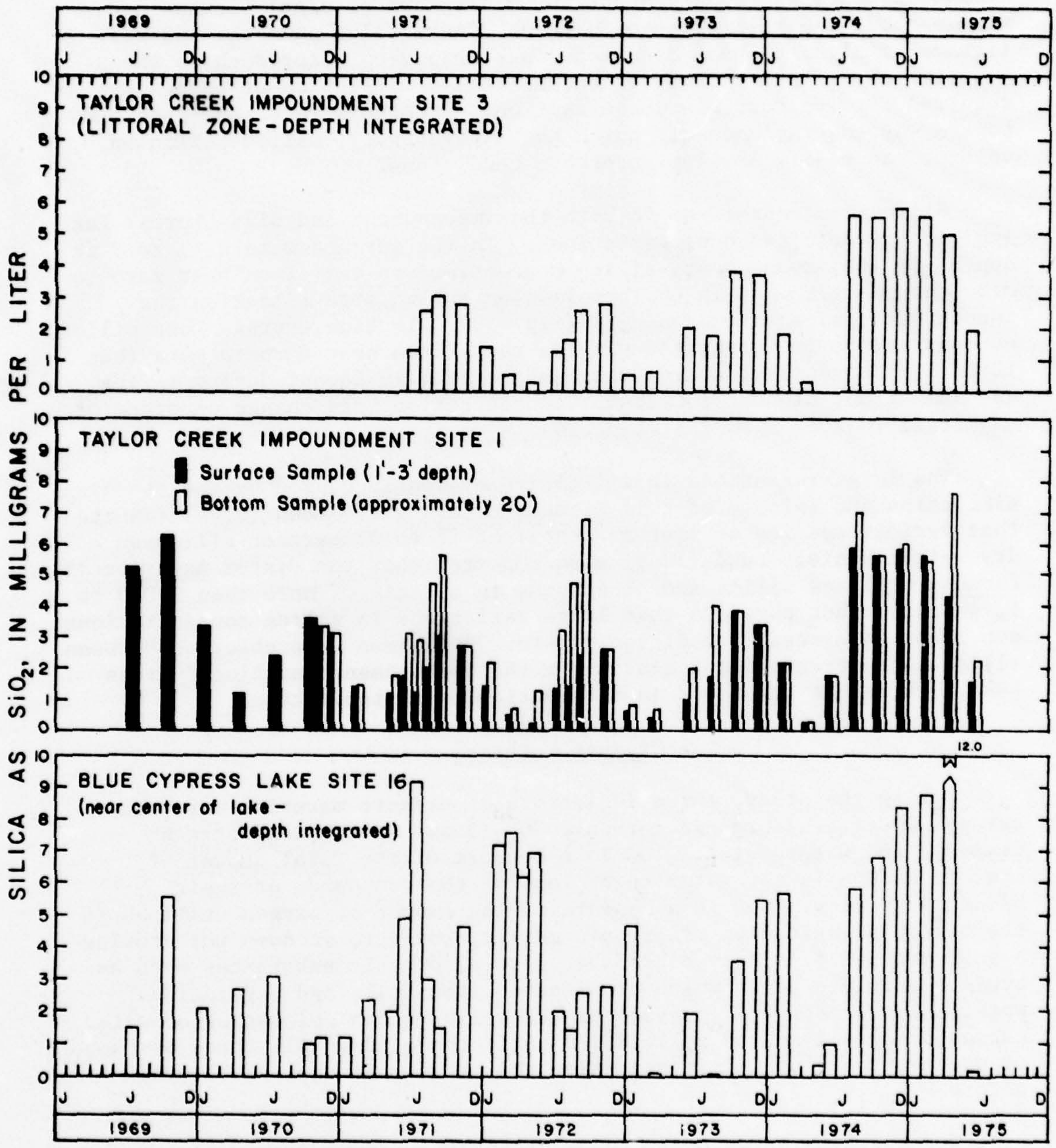

Figure 20.--Silica concentrations in Taylor Creek Impoundment and Blue Cypress Lake.

Table 6.--Statistical summary of data on organic carbon, BOD, and water color in Taylor Creek Impoundment and Blue Cypress Lake. (Includes all sampling depths; all data from point samples).

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Taylor Creek Impoundment (All Sites)					
Total Organic Carbon, mg/L	128	8.0	34	18.4	5.0
5-day Biochemical oxygen demand, mg/L	136	.0	5.7	1.6	1.0
Color Platinum - Cobalt units	124	45	260	130	44
Taylor Creek Impoundment (Site 1)					
Total Organic Carbon, mg/L	64	8.0	34	19.2	5.4
5-day Biochemical oxygen demand, mg/L	67	.0	3.8	1.5	.9
Color Platinum - Cobalt units	62	45	240	132	4
Taylor Creek Impoundment (Site 3)					
Total Organic Carbon, mg/L	25	8.0	25	17.5	4.4
5-day Biochemical oxygen demand, mg/L	26	.5	5.0	1.6	1.0
Color Platinum - Cobalt units	24	90	240	134	43
Blue Cypress Lake (All Sites)					
Total Organic Carbon, mg/L	38	11	63	21.7	8.5
5-day Biochemical oxygen demand, mg/L	42	0.3	3.0	1.1	.5
Color Platinum - Cobalt units	38	50	320	128	51
Blue Cypress Lake (Site 16)					
Total Organic Carbon, mg/L	28	12	63	22.0	9.5
5-day Biochemical oxygen demand, mg/L	32	.3	3.0	1.1	.6
Color Platinum - Cobalt units	30	50	320	129	57

organic matter concentration of 35 to 45 mg/L. Seasonal or long-term trends were not apparent; however, TOC concentrations increased with depth in the impoundment during stratification due to algal decomposition and release of organic matter.

Average BOD was slightly higher in the impoundment (1.6 mg/L) than in Blue Cypress Lake (1.1 mg/L). BOD was generally highest in the summer when organic production by algae, and other organisms, was greatest. A long-term decrease in BOD was observed in the impoundment (fig. 21). From 1969 through 1972, at site 1 (surface), BOD frequently exceeded 3 mg/L. Since 1972, BOD rarely has exceeded 2 mg/L and generally has been about 1 mg/L. In Blue Cypress Lake BOD rarely exceeded 1.5 mg/L, a level that no doubt represents natural background conditions.

In both Taylor Creek Impoundment and Blue Cypress Lake the average water color was approximately 130 platinum-cobalt units, however, the range and variability in color were greater in Blue Cypress Lake (table 6). No seasonal, long-term, or vertical variation was apparent. Water color tends to increase, however, after a heavy rain which flushes organic matter including humic substances into the impoundment and Blue Cypress Lake. The high color of the water severely restricts light penetration and consequently is a limiting factor in primary production. Secchi disk transparency measurements in both the impoundment and Blue Cypress Lake averaged 30 in. This low transparency is due to water color and not to turbidity.

Major Chemical Constituents

The major chemical constituents include the following cations and anions: calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate, and fluoride. These constituents make up most of the inorganic dissolved solids in water and to a large degree govern certain chemical and physical characteristics of water. The sum of these constituents is reported as dissolved solids (sum). Another measure of dissolved solids is the residue on evaporation at 180°C. This measurement which includes the above constituents plus all other dissolved inorganic and organic compounds is also reported. Calcium and magnesium ions are responsible for the hardness of water, and bicarbonate concentration to a large degree governs the buffering capacity of water and tends to regulate the pH. All of the above cations and anions carry an electrical charge which contributes to the specific conductance of water. Measurements of specific conductance can provide good estimates of dissolved solids concentrations and, in many instances, concentrations of the individual cations and anions.

The water in Taylor Creek Impoundment and Blue Cypress Lake is classified as a mixed chemical type in which calcium, sodium, bicarbonate, and chloride are the dominant ions. The concentration of dissolved solids (residue) in the impoundment (all sites) averaged 89

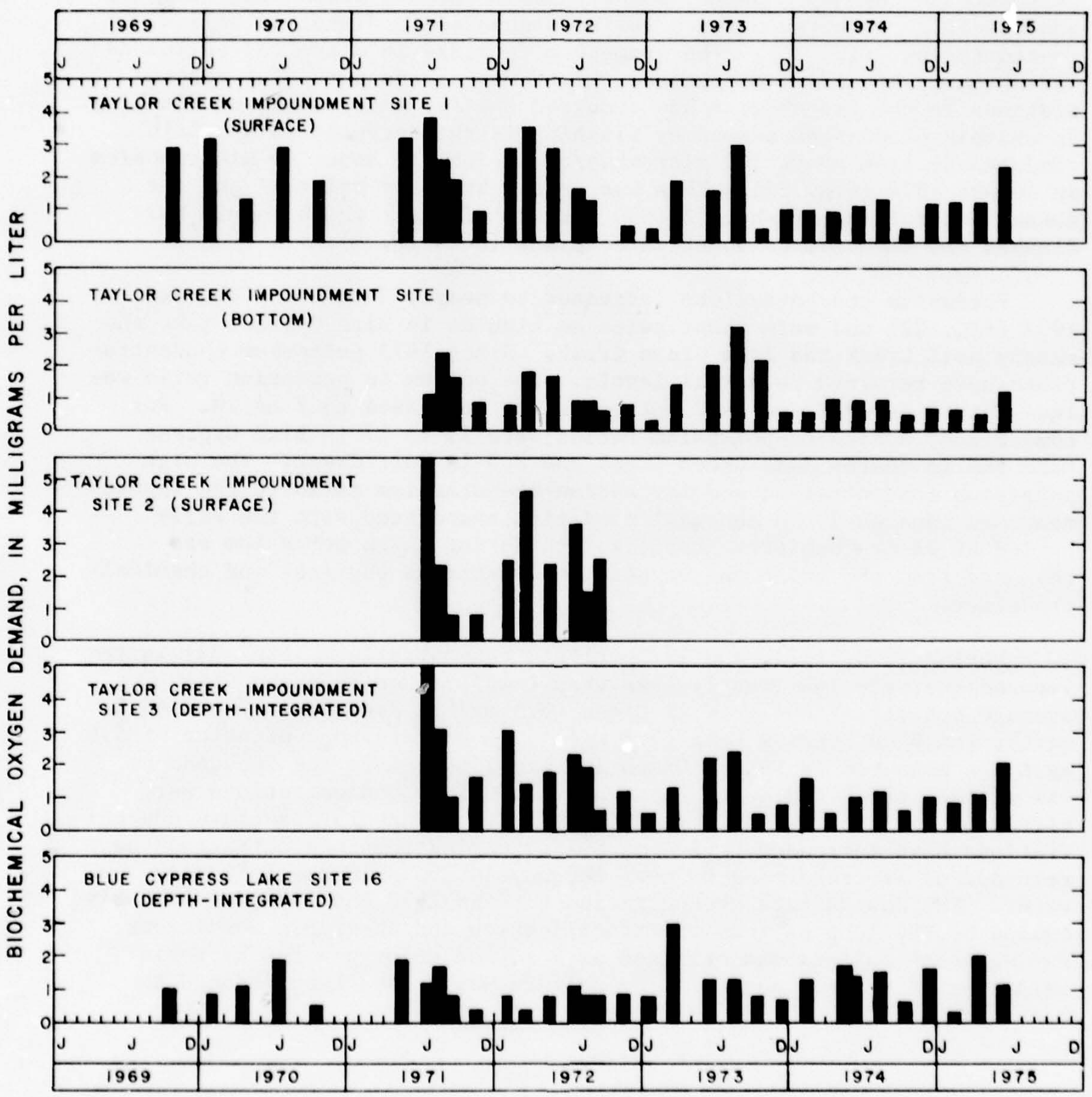

Figure 21.--BOD concentrations in Taylor Creek Impoundment and Blue Cypress Lake.

mg/L (table 7), about one-half the average concentration in Blue Cypress Lake. Water in the impoundment has an average hardness of 30 mg/L as $CaCO_3$ and is classified as soft, whereas water in Blue Cypress Lake with an average hardness of 61 mg/L is classified as moderately hard.

The concentrations of most major constituents varied seasonally in response to changes in rainfall and climatic conditions. Long-term changes have been observed in the concentrations of a few major constituents in the impoundment, notably, bicarbonate, potassium, sulfate, and specific conductance which reflects changes in dissolved solids concentration (fig. 22). The long-term decrease in dissolved solids as indicated by specific conductance, bicarbonate, and potassium concentrations in the impoundment has occurred chiefly as a result of flushing. An example of changes caused by flushing is the decrease in specific conductance from about 100 micromhos/cm in June to about 60 micromhos/cm in August 1974 (fig. 22). This was caused by heavy rainfall and the subsequent release of about 80,000 acre-ft of water which should have flushed the impoundment about three times (see fig. 8).

Potassium concentrations increased to nearly 3 mg/L in 1971 and 1972 (fig. 22) and were about twice as high as in Blue Cypress Lake and nearby Wolf Creek and Jane Green Creek. Since 1972 potassium concentrations have returned to normal levels. The sodium to potassium ratio was less than 4 in 1971 and 1972 but has since increased to 7 to 10. For comparison, sodium-to-potassium ratios were 15 to 17 in Blue Cypress Lake and in nearby Jane Green Creek and 8.5 in Wolf Creek. The high potassium concentration and low sodium-to-potassium ratio in the impoundment was apparently an abnormal condition associated with the early period of water chemistry stabilization during which potassium was released from the soils and vegetation by various physical and chemical processes.

During 1970, 1971, and 1972 sulfate concentrations (fig. 22) in the impoundment were low (mostly less than 1 mg/L) when compared with average concentrations in Wolf Creek (3.5 mg/L), Jane Green Creek (5.2 mg/L), and Blue Cypress Lake (9.2 mg/L). A sulfate concentration of 5.6 mg/L was measured in Taylor Creek in July 1969 before the impoundment was filled, which indicates that natural sulfate concentrations were higher in the creek than in the impoundment. Since 1972 sulfate concentrations have increased to 2-4 mg/L, indicating that concentrations have returned or are returning to near the levels found in the inflowing water. The low sulfate concentration between 1970 and 1972 was probably caused by the long periods of stratification and anaerobic conditions during which sulfate was utilized as a source of oxygen for bacterial oxidation of organic matter. The sulfate would have been reduced to hydrogen sulfide.

Table 7.--Statistical summary of data on major chemical constituents in Taylor Creek Impoundment and Blue Cypress Lake. (Results expressed in milligrams per liter except for specific conductance; includes all sampling depths.)

Taylor Creek Impoundment (All Sites)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Calcium (Ca)	47	5.0	18	9.1	2.0
Magnesium (Mg)	47	1.2	2.1	1.7	.26
Sodium (Na)	57	4.6	11	9.0	1.8
Potassium (K)	57	.2	3.7	1.7	1.0
Bicarbonate (HCO_3)	126	16	55	27	7.3
Chloride (Cl)	45	8.0	21	15.7	3.4
Sulfate (SO_4)	57	.0	8.3	1.9	2.1
Fluoride (F)	47	.0	.4	.15	.08
Dissolved solids (residue)	46	49	138	89	16
Dissolved solids (sum)	46	41	85	57	10
Hardness ($CaCO_3$)	47	20	52	30	5.7
Specific Conductance (µmhos/cm)	153	53	205	106	25

Taylor Creek Impoundment (Site 1)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Calcium (Ca)	26	6.5	18	9.4	2.4
Magnesium (Mg)	26	1.3	2.1	1.7	.3
Sodium (Na)	31	4.6	11	8.9	1.9
Potassium (K)	31	.3	3.7	1.7	.9
Bicarbonate (HCO_3)	64	16	55	27	8.5
Chloride (Cl)	26	8.0	21	15.5	3.6
Sulfate (SO_4)	32	.0	6.6	1.7	1.9
Fluoride (F)	26	.0	.2	.13	.06
Dissolved solids (residue)	26	66	138	89	16
Dissolved solids (sum)	26	41	85	57	12
Hardness ($CaCO_3$)	26	22	52	30	6.4
Specific Conductance (µmhos/cm)	77	63	200	107	25

Taylor Creek Impoundment (Site 3)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Calcium (Ca)	9	5.0	12.0	8.1	2.0
Magnesium (Mg)	9	1.2	2.0	1.6	.3
Sodium (Na)	11	4.6	11	8.6	1.9
Potassium (K)	11	.2	3.1	1.4	1.0
Bicarbonate (HCO_3)	23	17	34	24	5.6
Chloride (Cl)	8	8.1	19	14.4	3.3
Sulfate (SO_4)	10	.2	5.6	2.3	2.1
Fluoride (F)	9	.0	.4	.2	.1
Dissolved solids (residue)	8	49	102	82	16
Dissolved solids (sum)	8	41	59	52	7.5
Hardness ($CaCO_3$)	9	20	37	27	5.4
Specific Conductance (µmhos)	24	60	125	96	18

Blue Cypress Lake (Site 16)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Calcium (Ca)	17	9.8	22	17.5	3.6
Magnesium (Mg)	17	2.2	5.2	3.9	0.8
Sodium (Na)	19	12	31	22.5	4.7
Potassium (K)	19	.8	2.5	1.3	.4
Bicarbonate (HCO_3)	29	25	54	39	6
Chloride (Cl)	17	23	66	46	11
Sulfate (SO_4)	19	.8	16	9.2	4.2
Fluoride (F)	17	.2	.5	.3	.1
Dissolved solids (residue)	17	105	240	176	35
Dissolved solids (sum)	16	67	160	125	28
Hardness ($CaCO_3$)	17	34	76	61	12
Specific Conductance (µmhos)	36	129	323	248	46

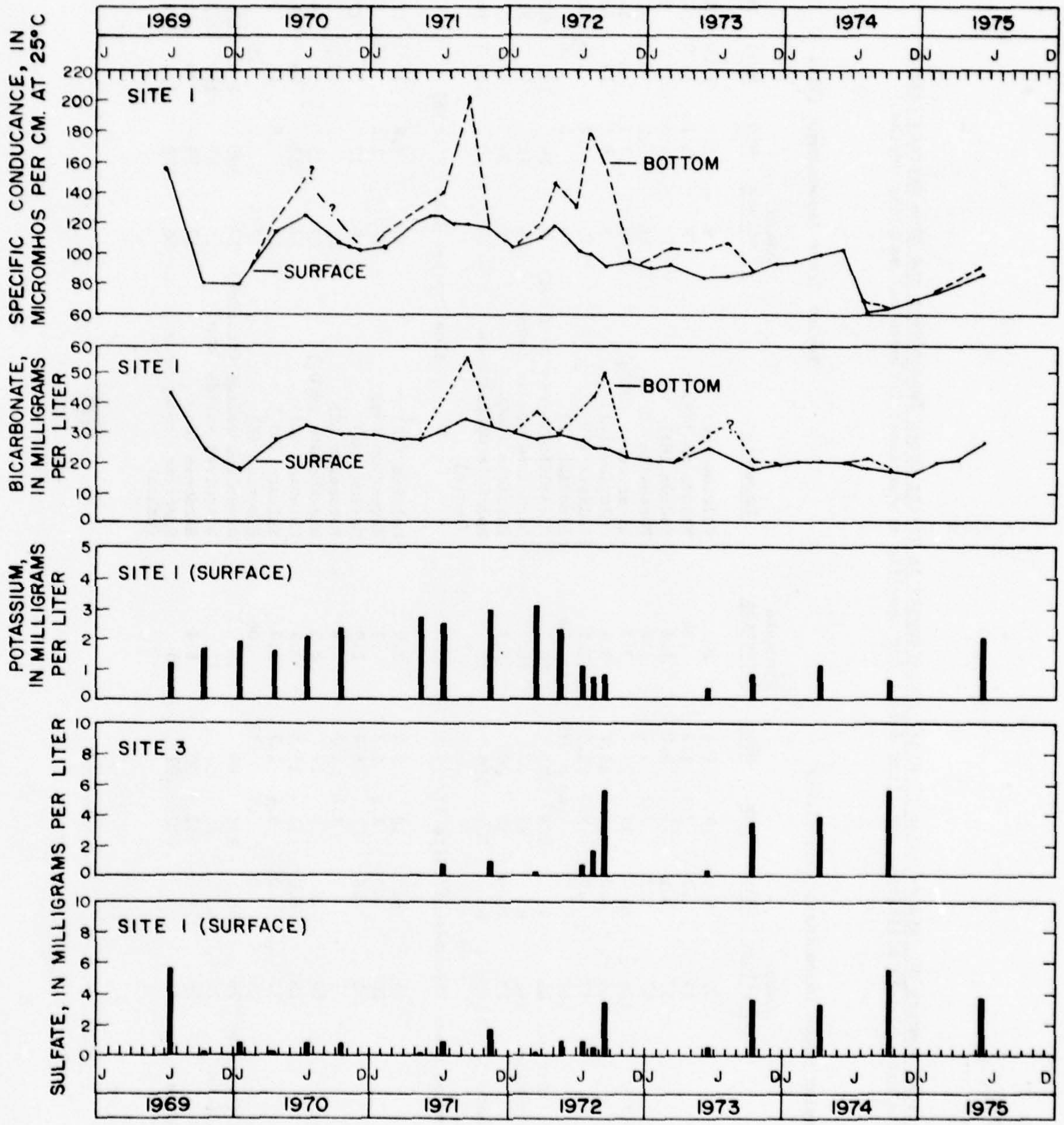

Figure 22.--Variations in specific conductance, bicarbonate, potassium, and sulfate in Taylor Creek Impoundment.

Bicarbonate concentration in the impoundment increases with depth during stratification (fig. 22). The high concentrations in the hypolimnion result mainly from the decomposition of algae which produces carbon dioxide (CO_2) as shown by the equation on page 24. Part of the CO_2 subsequently hydrolyzes to form bicarbonate, as discussed earlier, and this lowers the pH. A long-term decrease in bicarbonate concentration has been observed (fig. 22). As with other major constituents, this decrease is probably due to flushing of the impoundment and, additionally, to a reduction in the quantity of oxidizable material in the impoundment.

Specific conductance and the concentration of major constituents in Blue Cypress Lake varied in response to hydrologic and climatic conditions, and were probably affected to some degree by agricultural use of water south and east of the lake. During the 7-year period (1969-75) specific conductance, at site 16, ranged from about 120 to 320 micromhos/cm (fig. 23) and illustrates the variation in specific conductance with hydrologic conditions. Specific conductance generally increases with decreasing lake stage (dry season) and decreases with increasing lake stage (wet season).

Trace Metals

A statistical summary of data on nine trace metals in the impoundment and in Blue Cypress Lake is presented in table 8. Comparison of these data with recommended criteria for various water uses given in Water Quality Criteria (National Academy of Sciences and National Academy of Engineering, 1973) (table 9) shows that the mean concentrations for all metals, except iron, were several times to an order of magnitude lower than the recommended criteria for the uses given. The iron concentrations were high primarily in the hypolimnion of the impoundment due to anaerobic conditions which greatly increased the solubility of iron. Iron concentrations are naturally high in water throughout the upper St. Johns basin. Goolsby and others (1976) reported that the mean concentration of dissolved iron in 166 samples from the upper St. Johns basin was 210 μg/L (micrograms per liter) and the total iron concentration in 60 samples averaged 390 μg/L. Manganese concentrations in the hypolimnion of the impoundment occasionally exceeded the recommended criterion for public water supply (50 μg/L) but elsewhere maximum concentrations were well below the criterion. Of the remaining metals, the maximum concentrations of only two exceeded the recommended criteria for all water uses. These were total lead and total mercury, and these metals exceeded the criterion for each in only 1 or 2 samples. Mean concentrations of both were many times lower than the criteria.

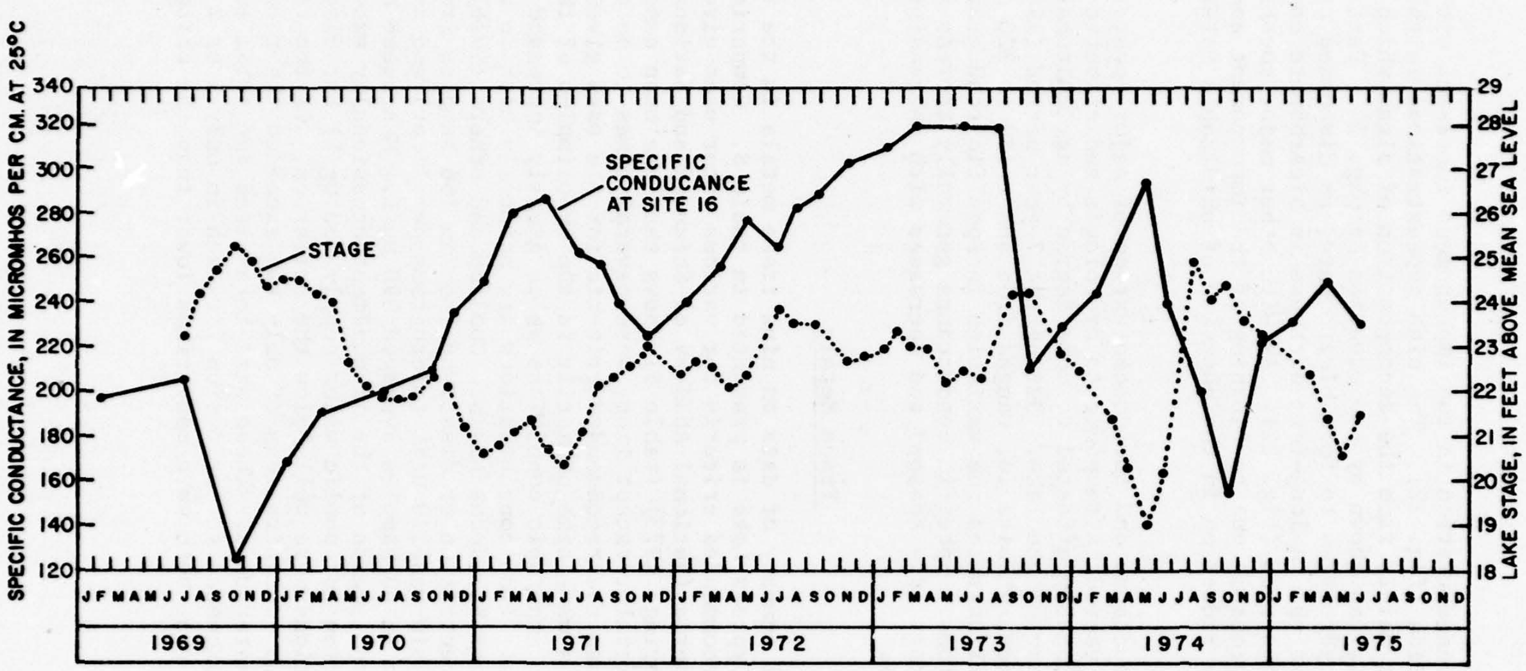

Figure 23.--Variations in specific conductance and lake stage in Blue Cypress Lake.

Table 8.—Statistical summary of data on trace metals in Taylor Creek Impoundment and Blue Cypress Lake. (Results expressed in micrograms per litre; includes all sampling depths.)

Taylor Creek Impoundment (All Sites)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Total Arsenic	23	0	30	6.7	7.3
Total Cadmium	24	0	2	.2	.5
Dissolved Copper	48	0	20	2.3	5.2
Dissolved Iron	62	50	3100	301	524
Total Iron	49	90	3100	371	510
Dissolved Lead	43	0	10	2.3	2.8
Total Lead	43	0	42	3.9	6.6
Dissolved Manganese	45	0	120	21	29
Total Manganese	41	0	110	18	24
Total Mercury	25	0	.6	.14	.19
Dissolved Strontium	39	10	140	75	30
Total Zinc	39	0	230	24	40

Taylor Creek Impoundment (Site 1)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Total Arsenic	13	0	30	7.5	8.7
Total Cadmium	14	0	2	.2	.6
Dissolved Copper	21	0	10	2.4	.4
Dissolved Iron	30	50	3100	462	722
Total Iron	20	100	3100	514	766
Dissolved Lead	22	0	10	2.2	2.9
Total Lead	21	0	12	2.5	3.1
Dissolved Manganese	22	0	120	28	38
Total Manganese	19	0	110	22	32
Total Mercury	13	.0	.3	.09	.11
Dissolved Strontium	23	10	140	76	33
Total Zinc	19	0	230	32	54

Taylor Creek Impoundment (Site 3)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Total Arsenic	6	0	17	6.5	6.3
Total Cadmium	6	0	1	.2	.4
Dissolved Copper	9	0	20	2.2	6.7
Dissolved Iron	12	60	160	112	30
Total Iron	11	90	810	226	197
Dissolved Lead	9	0	8	2.4	2.7
Total Lead	8	0	10	4.2	3.2
Dissolved Manganese	8	0	10	7.5	4.6
Total Manganese	9	0	29	8.8	9.0
Total Mercury	6	.0	.6	.2	2
Dissolved Strontium	8	40	110	68	32
Total Zinc	7	0	70	24	27

Blue Cypress Lake (Site 16)

Parameter	Number of values	Min.	Max.	Mean	Standard deviation
Total Arsenic	9	1	30	10	10
Total Cadmium	9	0	1	.1	.3
Dissolved Copper	16	0	10	2.8	4.4
Dissolved Iron	18	30	390	166	77
Total Iron	13	130	810	308	169
Dissolved Lead		0	7	1.3	2.2
Total Lead	12	0	77	9.4	22
Dissolved Manganese	17	0	20	4.1	6.2
Total Manganese	13	0	20	8.8	7.0
Total Mercury	10	.0	.9	.2	.3
Dissolved Strontium	16	240	650	431	111
Total Zinc	15	0	50	17	15

TABLE 9.--Summary of water-quality criteria for trace metals (National Academy of Sciences, National Academy of Engineering, 1973). Values expressed in micrograms per liter except where noted.

Constituent	Agriculture (Irrigation)	Agriculture (Livestock)	Freshwater (Aquatic Life)	Freshwater (Wildlife)	Freshwater (Public Supply)	Marine Water (Aquatic Life)
Aluminum	5.0 mg/L 20.0 mg/L (20 yrs.)	5.0 mg/L	--	--	--	1/100 (0.01) 96-hr. LC_{50} 1.5 mg/L 1/10 LD_{50}
Arsenic	0.10 mg/L 2.0 mg/L (20 yrs.)	0.2 mg/L	--	--	0.1 mg/L	1/100 (0.01) 96-hr. LC_{50} 0.05 mg/L
Cadmium	0.01 mg/L 0.05 mg/L (20 yrs.)	50 ug/L	0.03 mg/L hard H_2O 0.004 mg/L soft H_2O	--	0.01 mg/L	1/100 (0.01) 96-hr. LC_{50} 0.01 mg/L
Chromium	0.1 mg/L 1.0 mg/L (20 yrs.)	1.0 mg/L	0.05 mg/L	--	0.05 mg/L	1/100 (0.01) 96-hr. LC_{50} 0.1 mg/L
Cobalt	0.05 mg/L 5.0 mg/L (20 yrs.)	1.0 mg/L	--	--	--	--
Copper	0.20 mg/L 5.0 mg/L	0.5 mg/L	1/10 (0.1) 96-hr. LC_{50}	--	1 mg/L	1/100 (0.01) 96-hr. LC_{50} 0.05 mg/L
Iron	5.0 mg/L 20.0 mg/L (20 yrs.)	No limit	--	--	0.3 mg/L	0.3 mg/L
Lead	5.0 mg/L 10.0 mg/L	0.1 mg/L	0.03 mg/L	--	0.05 mg/L	1/50 (0.02) 96-hr. LC_{50} 0.01 LD_{50}
Manganese	0.20 mg/L 10.0 mg/L (20 yrs.)	No limit	--	--	0.05 mg/L	1/50 (0.02) 96-hr. LC_{50} 0.01 mg/L
Mercury Inorganic		1.0 ug/L	0.2 ug/L totl conc. 0.5 ug/g body burden conc. tot. hg	0.5 ug/L in fish	0.002 mg/L total	1/100 (0.01) 96-hr. IC_{50}
Mercury Organic	--	--	0.2 ug/L total conc. 0.05 ug/L avg. conc. 0.5 ug/g body burden conc. tot. hg	--	--	--
Nickel	0.2 mg/L 2.0 mg/L (20 yrs.)	--	1/50 (0.02) 96-hr. LC_{50}	--	--	1/50 (0.02) 96-hr. LC_{50} 0.1 mg/L
Zinc	--	25 mg/L	5/1000 (0.005) 96-hr. LC_{50}	--	5 mg/L	1/100 (0.01) 96-hr. LC_{50} 0.1 mg/L

CHEMISTRY OF BOTTOM SEDIMENTS

Bottom sediments play an important role in regulating the chemistry of lakes and reservoirs, and are indicators of trophic-state conditions. Bottom sediments may act as major geochemical controls for such dissolved constituents as orthophosphate, ammonia-nitrogen, iron, manganese, and other trace metals and probably greatly influence concentrations of carbon dioxide, oxygen, and dissolved organic carbon. Depending on hydrologic and environmental conditions, bottom sediments may rapidly deplete DO from the overlying water and release phosphorus and iron; under a different set of conditions phosphorus and iron may be removed from the overlying water by bottom sediments. These effects have been observed in laboratory experiments (Goolsby and McPherson, 1970, p. 29; Brezonik and others, 1969, p. 32) and are consistent with data collected in natural systems.

The composition of bottom sediments reflects to a large degree the productivity of lakes and the input of nutrients and organic matter from the lake drainage basin. Organic matter, whether produced in the lake (autochthonous) or transported into the lake (allochthonous), accumulates in the deep parts of the lake and in areas of little circulation. Large accumulations of sediment with high organic content reflect high productivity or allochthonous sediment input or both whereas sediment with low organic content reflects low productivity and low allochthonous input.

The chemical composition of bottom sediments in Taylor Creek Impoundment, Blue Cypress Lake and several other sites in the upper St. Johns River basin is given in tables 10 and 11. Most of the sediment in the impoundment is sand, with a small amount of clay, and at the time of the analyses, was probably still fairly representative of the terrestrial soils prior to inundation. Organic content is low as indicated by the relatively low concentration of organic carbon (table 10). In time, sediment accumulation and organic content will probably increase in the deeper parts of the impoundment.

Bottom sediments, at site 2, on the western side of Blue Cypress Lake are composed of coarse sand and are very low in organic content. The organic content begins to increase approximately one-quarter of the way across the lake in a west to east direction and on the east and northeast sides of the lake organic muck accumulations are at least several feet thick. This organic sediment is largely finely divided silt and clay-size organic detritus. The organic carbon content is 35 to 40 percent. If the total organic content is assumed to be twice the organic carbon content, the sediment is 70 to 80 percent organic matter. It also contains 2 to 3 percent organic nitrogen, large quantities of iron and measurable amounts of chromium, copper, lead, manganese, nickel, and zinc (table 11).

Table 10.--Bottom sediment analyses - Upper St. Johns River basin. (Results in milligrams per kilogram dry weight, except pH.)

Date	Location	Organic carbon(C)	Kjeldahl nitrogen(N)	Ammonia nitrogen(N)	Total phosphorus(P)	Total Iron	pH
05-01-70	Ft. Drum Creek (Creek Bed)	248,000	12,700	370	980	1,400	6.2
05-01-70	Ft. Drum Creek (Dry Flood Plain)	313,000	9,200	110	790	1,100	5.7
04-30-70	Blue Cypress Creek (Creek Bed)	163,300	8,000	230	610	6,300	6.0
04-30-70	Blue Cypress Creek (Dry Flood Plain)	247,200	21,100	510	1,440	400	5.4
05-01-70	St. Johns Headwaters at Highway 60	289,000	14,200	190	650	3,400	7.4
10-21-69	Jane Green Creek (Shallow Creek Bed)	136,500	400	-	40	-	-
04-28-70	Jane Green Creek (Deep Pool)	267,300	24,900	200	430	13,500	6.1
10-20-69	Taylor Creek Impoundment (Site 1)	24,600	300	-	180	-	-
04-27-70	Taylor Creek Impoundment (Site 1)	17,100	800	20	610	3,400	6.8
07-14-71	Taylor Creek Impoundment (Site 1)	20,200	1,600	-	-	-	-
03-28-72	Taylor Creek Impoundment (Site 1)	12,900	400	-	-	-	-
08-15-72	Taylor Creek Impoundment (Site 1)	7,600	390	30	61	600	-
07-14-71	Taylor Creek Impoundment (Site 2)	57,100	2,600	-	-	-	-
03-28-72	Taylor Creek Impoundment (Site 2)	100,700	3,900	-	-	-	-
03-28-72	Taylor Creek Impoundment (Site 3)	39,500	2,300	-	-	-	-
10-22-69	Blue Cypress Lake(near West Shore)Site 17	55,800	500	-	50	-	-
04-29-70	Blue Cypress Lake(near West Shore)Site 17	0	200	20	30	300	-
07-15-71	Blue Cypress Lake(near West Shore)Site 17	2,300	400	-	-	-	-
03-29-72	Blue Cypress Lake(near West Shore)Site 17	2,100	300	-	-	-	7.3
08-17-72	Blue Cypress Lake(near West Shore)Site 17	5,400	3,580	210	31	30	7.8
04-29-70	Blue Cypress Lake (near Center) Site 16	399,200	23,500	460	980	600	6.4
03-29-72	Blue Cypress Lake (near Center) Site 16	355,000	25,500	-	-	-	6.8-7.4
08-17-72	Blue Cypress Lake (near Center) Site 16	360,000	31,000	190	840	13,200	-

Table 10.--Bottom sediment analyses - Upper St. Johns River basin.--(continued)

Date	Location	Organic carbon(C)	Kjeldahl nitrogen(N)	Ammonia nitrogen(N)	Total phosphorus(P)	Total Iron	pH
10-28-69	Lake Hellen Blazes (near Outlet)	438,000	28,800	-	530	-	-
05-05-70	Lake Hellen Blazes (near Inlet)	402,000	25,800	300	550	1,000	6.4
05-05-70	Lake Hellen Blazes (near Outlet)	437,000	25,100	390	460	3,400	6.6
05-05-70	Sawgrass Lake (near Outlet)	430,000	32,300	300	520	1,000	6.7
05-04-70	St. Johns River (near Lake Washington)	4,600	400	20	90	800	8.1
05-04-70	Lake Washington (near Inlet)	85,300	5,600	50	90	7,000	6.9
10-28-69	Lake Washington (at Water Plant Intake)	278,000	18,600	-	740	-	-
05-04-70	Lake Washington (at Water Plant Intake)	296,000	26,700	330	580	900	7.0
05-05-70	Lake Washington (near Outlet)	76,700	5,300	80	180	4,000	7.0
05-06-70	Lake Winder (near Inlet)	35,700	4,400	90	350	5,400	6.6
11-05-69	Lake Poinsett (near Inlet)	33,700	2,900	-	180	-	-
05-06-70	Lake Poinsett (near Inlet)	2,700	200	20	50	800	7.4
05-07-70	St. Johns River (near Highway 520)	36,400	3,700	60	310	3,000	6.6
05-08-70	St. Johns River (1/2 mile south of Econlockhatchee River)	200	200	20	80	1,000	7.8
05-08-70	St. Johns River (1/2 mile north of Econlockhatchee River)	0	100	20	60	3,600	-
05-08-70	Econlockhatchee River (near Mouth)	5,000	700	30	210	4,400	7.1
10-27-69	St. Johns River (at Highway 46)	37,100	3,000	-	260	-	-
05-08-70	St. Johns River (at Highway 46)	2,800	500	30	80	400	7.6

Table 11.--Trace metal analyses and particle size distribution of bottom sediments from Taylor Creek Impoundment and Blue Cypress Lake. (Trace metal results in micrograms per gram dry weight; particle size results are in percent.)

Constituents or Property	Taylor Creek Impoundment Site 1 08-15-72	Blue Cypress Lake near center Site 16 08-17-72	Blue Cypress Lake near west shore Site 17 08-17-72
Trace metals, µg/g			
Arsenic	4	3	3
Cadmium	< 1	7	< 1
Chromium	1	12	1
Cobalt	0	4	0
Copper	< 1	10	< 1
Iron	585	13,200	32
Mercury	.02	.00	.00
Lead	6	68	4
Manganese	7	60	1
Nickel	1	13	1
Selenium	0	< 1	0
Zinc	2	44	1
Particle size			
Greater than 2mm	0.2	0.0	0.3
Sand percent	93.4	24.1	96.4
Silt percent	.0	61.8	.0
Clay percent	6.4	14.1	3.3

The pH of a sample with high organic content collected near the center of Blue Cypress Lake (site 16) with an Ekman dredge in March 1972 ranged from 6.8 to 7.4 depending on where the pH electrodes were placed in the sediment. The observed variation may reflect a vertical gradient in pH. The redox potential (Eh) of the sediment sample ranged from -20 to +25 mv indicating reducing conditions. The Eh of water 1 foot above the bottom was 435 mv. The pH of sediment collected near the west shore of the lake (site 17) in March 1972 was 7.3 and the Eh ranged from 175 to 345 mv. The sediment was coarse quartz sand and its uppermost surface was green in color, probably due to benthic algae or photosynthetic bacteria. The sediment at this site was tinged green on several other occasions also.

Although chemical and thermal stratification does not normally occur in Blue Cypress Lake, reducing conditions do occur in the organic sediment. These conditions greatly increase the solubility of iron and orthophosphate in the interstitial water. These substances can in turn be recycled to the overlying water, partly by diffusion but probably more significantly by wind which creates turbulence and frequently disturbs the flocculent organic bottom sediment. On windy days, the water contains noticeable amounts of suspended sediment. Nutrients probably are recycled from bottom sediments and interstitial water much more rapidly in Blue Cypress Lake than in Taylor Creek Impoundment.

The finely-divided organic sediment in Blue Cypress Lake may serve as a major food source for zooplankton. The zooplankton biomass per unit volume of water in the lake was several orders of magnitude greater than in Taylor Creek Impoundment.

No attempt was made to determine the source of the organic sediment in Blue Cypress Lake. However, the surrounding marsh is the likely source. Lake Hellen Blazes and Sawgrass Lake, on the main stem of the St. Johns River (fig. 1), also drain the headwater marshes and have accumulated highly organic bottom sediments (table 10) a part of which is coarse plant fragments. Drainage of the marshes and encroachment onto the floodplain have probably greatly increased the sediment input to the lakes in the last few decades.

PLANKTON

Phytoplankton

The phytoplankton, which constitute the algal component of the plankton, are major primary producers in lakes and reservoirs. Their numbers vary widely in response to available nutrients, temperature, growing seasons, and many other factors. Usually waters that are rich in nutrients sustain large numbers of phytoplankton and are subject to frequent phytoplankton "blooms."

The principal divisions of planktonic algae are: diatoms, green algae, and blue-green algae. Members of each of these divisions may bloom in large numbers under specific environmental conditions.

Diatoms require silica, in addition to other nutrients, for growth, and may be limited by low concentrations of this element. Large blooms of diatoms are uncommon in Florida lakes, probably because of low concentrations of dissolved silica in these waters (Shannon and Brezonik, 1972).

Blue-green algae differ from other types in that some of their members are able to assimilate gaseous nitrogen (N_2). The growth of these algae is not limited by low concentrations of inorganic nitrogen and they can bloom where other algae are inhibited.

Blooms of blue-green algae are often conspicuous because of their large biomass and because they float near the water surface and often discolor the water. In addition, metabolites and breakdown products released by some species not only impart bad tastes and odors to water but are toxic.

Blue-green algae usually dominate the phytoplankton community of eutrophic lakes in Florida. Anacystis (formerly called Microcystis), Anabaena, and Lyngbya are the most common genera in these lakes (Shannon and Brezonik, 1972).

In Taylor Creek Impoundment the total number of planktonic algae ranged from less than 20 to 100,000 cells/mL (figs. 24 and 25; table 12). Numbers exceeded 10,000 cells/mL in March 1972, and in June and August 1973 and 1974 and June 1975 at site 1 and 3 and in September 1972 at site 1. Blue-green algae were dominant in number in these "blooms" at both sites 1 and 3, except in August 1973 (site 1) when the green alga Chlorella sp. dominated. The blue-green alga Anabaena sp. dominated in March 1972 and June 1973. Another blue-green alga Anacystis sp., dominated in August 1973 and June and August 1974. Diatoms, mainly Melosira sp., were dominant in about 35 percent of the samples.

Numbers of phytoplankton in Taylor Creek Impoundment were statistically correlated with several parameters between November 1972 and June 1975. Numbers correlated positively at the 1 percent significance level with temperature and 5-day BOD. High temperatures increase biological metabolism and large concentrations of phytoplankton would also contribute to high BOD. Numbers of phytoplankton correlated positively at the 5 percent significance level with bicarbonate, organic nitrogen, and potassium, and negatively at the 5 percent significance level with nitrate. Although some of these simple correlations are difficult to explain, the correlation with organic nitrogen and with nitrate are expected. Phytoplankton populations grow by removing nitrate from the water and converting it into cellular organic nitrogen.

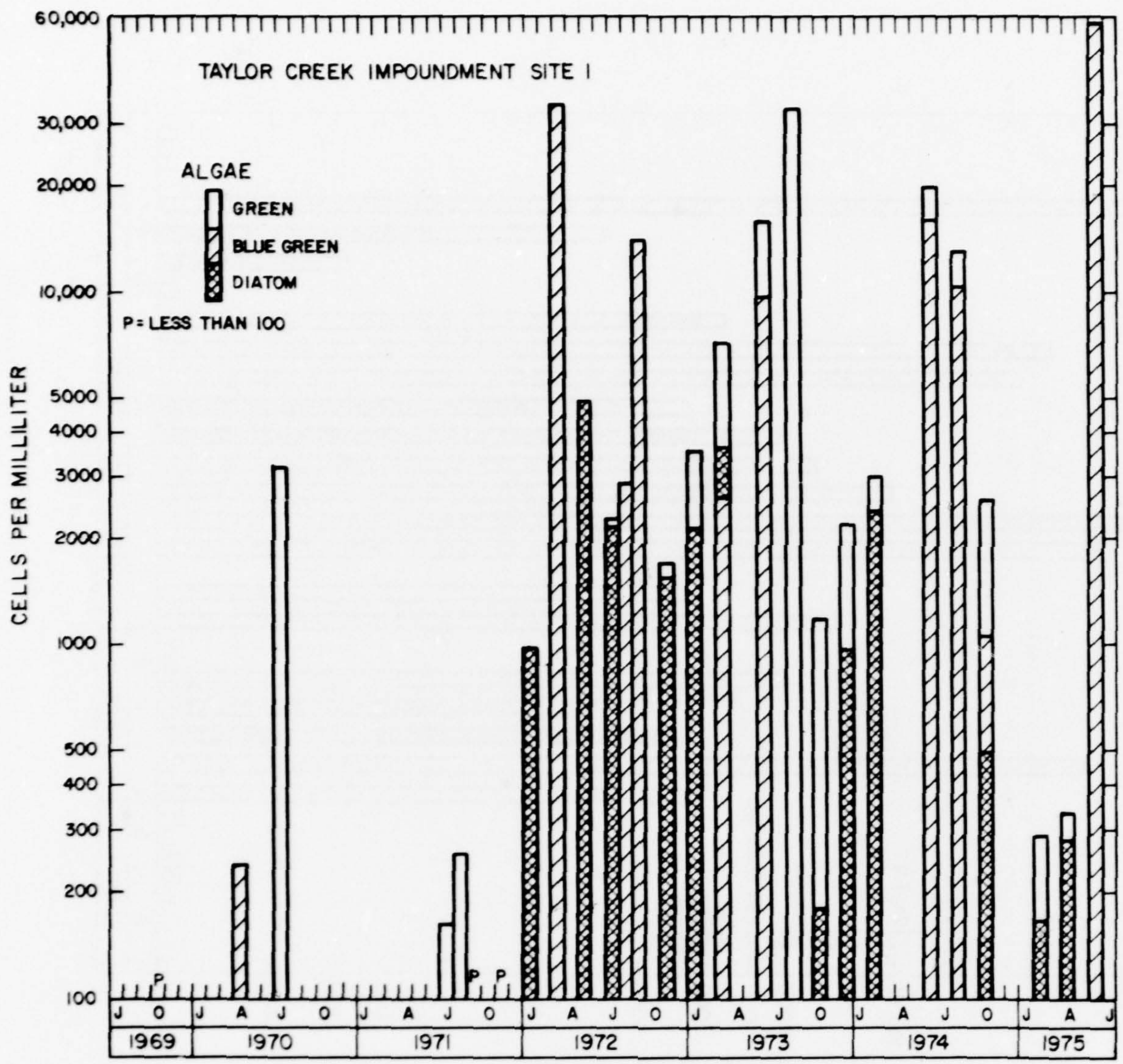

Figure 24.--Numbers of phytoplankton in Taylor Creek Impoundment at Site 1.

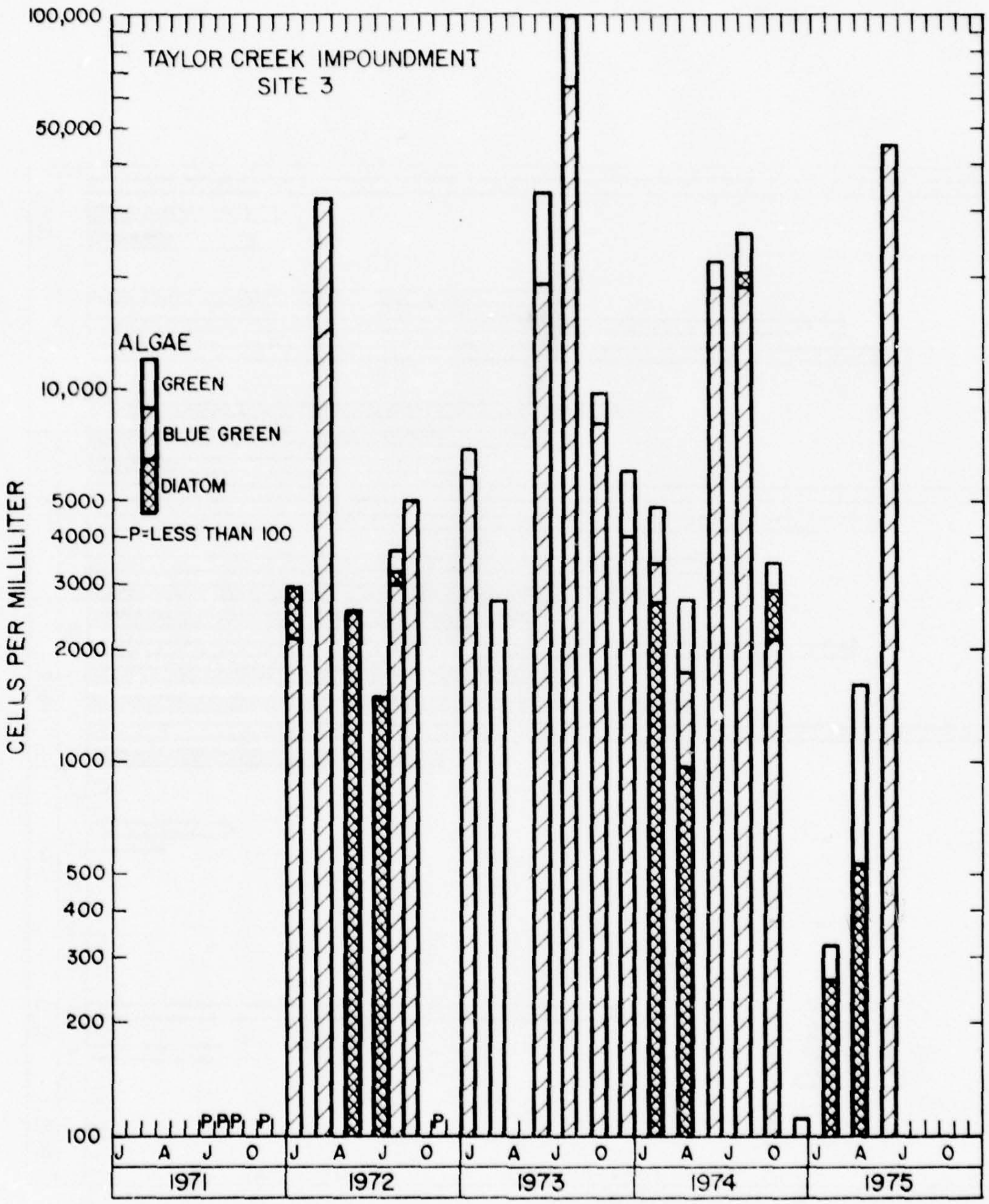

Figure 25.--Numbers of phytoplankton in Taylor Creek Impoundment at Site 3.

Table 12.--<u>Total number of plankton algae cells per mL in Taylor Creek Impoundment and Blue Cypress Lake</u>. (P, present but numbers less than 20 pr ml; B, blue green algae dominant; G, green algae dominant; D, diatoms dominants; E, Fuglenophytan dominant; C, Cryptomonas)

Date	Taylor Creek Impoundment			Blue Cypress Lake	
	Site 1	Site 2	Site 3	Site 16	Site 17
Oct 1969	P (D)	-	-	P (D)	-
Jan-Feb 1970	-	-	-	508 (B)	-
Apr-May 1970	238 (B)	-	-	78 (B)	-
July 1970	3,200 (G)	-	-	74,480 (B)	-
July 1971	161 (C)	59 (G)	64 (G)	24 (C)	29 (G)
Aug 1971	245 (C)	457 (G)	93 (G)	2,160 (D)	311 (D)
Sept 1971	P (B)	74 (E)	61 (B)	1,096 (D)	47 (D)
Nov 1971	57 (B)	22 (G)	48 (D)	P (D)	P (D)
Jan 1972	983 (D)	-	2,905 (B)	P (D)	P (G)
Mar 1972	30,400 (B)	33,740 (B)	32,000 (B)	P (D)	60 (D)
May 1972	4,993 (D)	7,615 (D)	2,561 (D)	348 (D)	80 (D)
July 1972	2,216 (D)	2,084 (D)	1,552 (D)	451 (D)	176 (D)
Aug 1972	2,826 (B)	3,504 (B)	3,790 (B)	720 (D)	P (D)
Sep 1972	14,077 (B)	5,984 (B)	4,922 (B)	846 (D)	109 (D)
Nov 1972	1,758 (D)	-	39 (D)	36 (B)	-
Jan 1973	3,500 (D)	-	6,800 (D)	850 (C)	-
Mar 1973	7,200 (B)	-	2,300 (G)	8,000 (G)	-
June 1973	16,000 (B)	-	33,000 (B)	7,800 (B)	-
Aug 1973	33,000 (G)	-	100,000 (B)	4,600 (B)	-
Oct 1973	1,200 (G)	-	9,700 (B)	1,600 (B)	-
Dec 1973	2,200 (G)	-	6,000 (B)	2,900 (B)	-
Feb 1974	3,000 (D)	-	4,800 (D)	13,000 (D)	-
Apr-May 1974	-	-	2,700 (D)	24,540 (B)	-
June 1974	20,000 (B)	-	22,000 (B)	24,000 (B)	-
Aug 1974	13,000 (B)	-	26,000 (B)	1,300 (D)	
Oct 1974	2,600 (D)	-	3,400 (B)	670 (D))	-
Dec 1974	-	-	110 (D)	700 (D))	-
Feb 1975	290 (D)	-	320 (D)	760 (G)	-
Apr 1975	340 (D)	-	1,600 (G)	1,200 (B)	-
June 1975	58,000 (B)	-	45,000 (B)	31,000 (B)	-

Diatoms require silica for growth and would be expected to correlate negatively with dissolved silica. However, there was no statistically significant correlation between silica concentration and diatom numbers in Taylor Creek Impoundment. Concentrations of silica changed seasonally. They were highest in the autumn and early winter and lowest in the spring. Diatom numbers were greatest in the summer of 1972 and the winters of 1973 and 1974. During 1973 and 1974 the numbers of diatoms were maximum, coincidental with sharp decreases in dissolved silica concentrations (figs. 26 and 27).

Algae in Blue Cypress Lake were generally less abundant than in Taylor Creek Impoundment. The total number in the lake, at site 16, ranged from less than 20 to 74,480 cells/mL (fig. 28). Numbers exceeded 10,000 cells/mL in July 1970 (Anabaena sp. dominant); in February (Melosira sp. and Anabaena sp. dominant), May (Anabaena sp.), and June (Anacystis sp.) 1974 and June (Anabaena sp.) 1975. Diatoms, mainly Melosira, sp., dominated in almost 50 percent of the samples (table 12).

Numbers of phytoplankton in Blue Cypress Lake correlated negatively with dissolved silica and orthophosphate, and positively with turbidity at the 5 percent significance level. Orthophosphate is required for phytoplankton growth, and would be expected to decrease as phytoplankton populations increase. Silica, as indicated earlier, is required by diatoms, which in Blue Cypress Lake constitute a significant part of the phytoplankton. Diatom blooms in 1971 and 1972 were preceded by peak silica concentrations in excess of 6 mg/L. During the blooms, concentrations of silica dropped to less than 2 mg/L. In 1973 diatoms were few in Blue Cypress Lake and silica concentrations were very low until October. Diatoms were abundant in February 1974, and silica concentrations were relatively high (5.7 mg/L). Silica concentrations and numbers of diatoms decreased to low levels in May 1974, but diatoms were abundant again in June 1974 (fig. 29).

In 1971-72 phytoplankton samples were collected near the center (site 16) and the west shore (site 17) of Blue Cypress Lake. Algae were more numerous in the center than near the shore (table 12). Primary productivity was also higher in the center than at the west shore as discussed in the section on primary productivity.

Plankton collected in net samples contain the larger members of the phytoplankton and the zooplankton. These larger organisms are often not collected in plankton bottle samples. Zooplankton, in particular, may avoid the device used to collect the water sample. Large plankters may be scarce compared with the small phytoplankters, but in biomass may constitute a major component of the plankton.

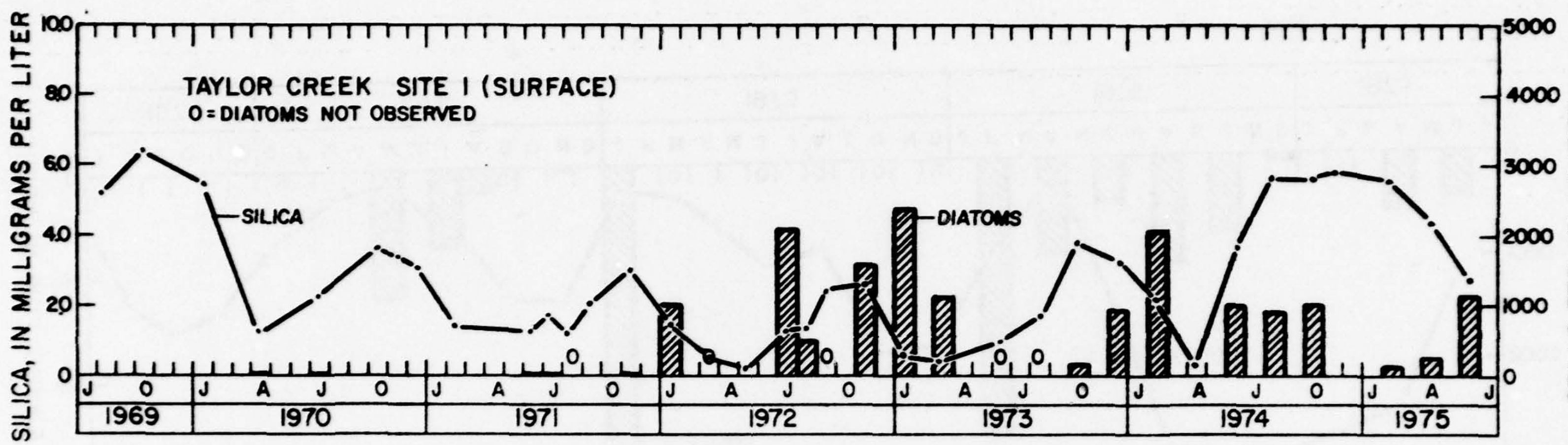

Figure 26.--Concentrations of dissolved silica and number of diatoms in Taylor Creek Impoundment at Site 1.

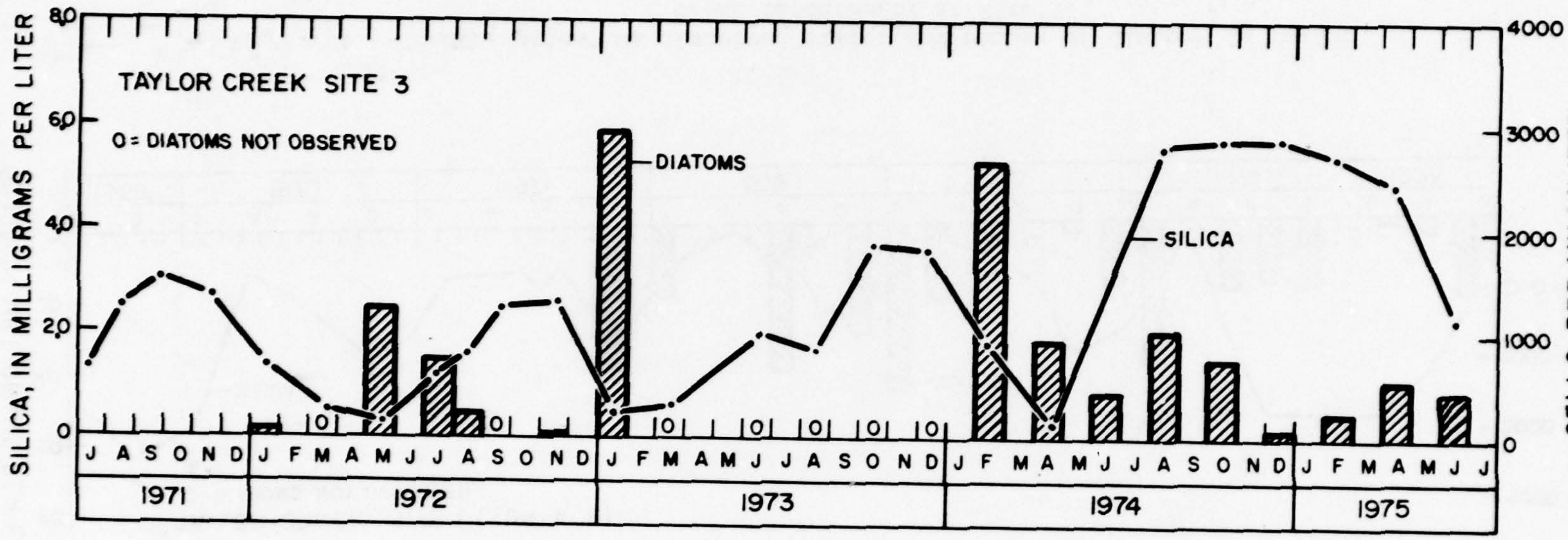

Figure 27.--Concentrations of dissolved silica and number of diatoms in Taylor Creek Impoundment at Site 3.

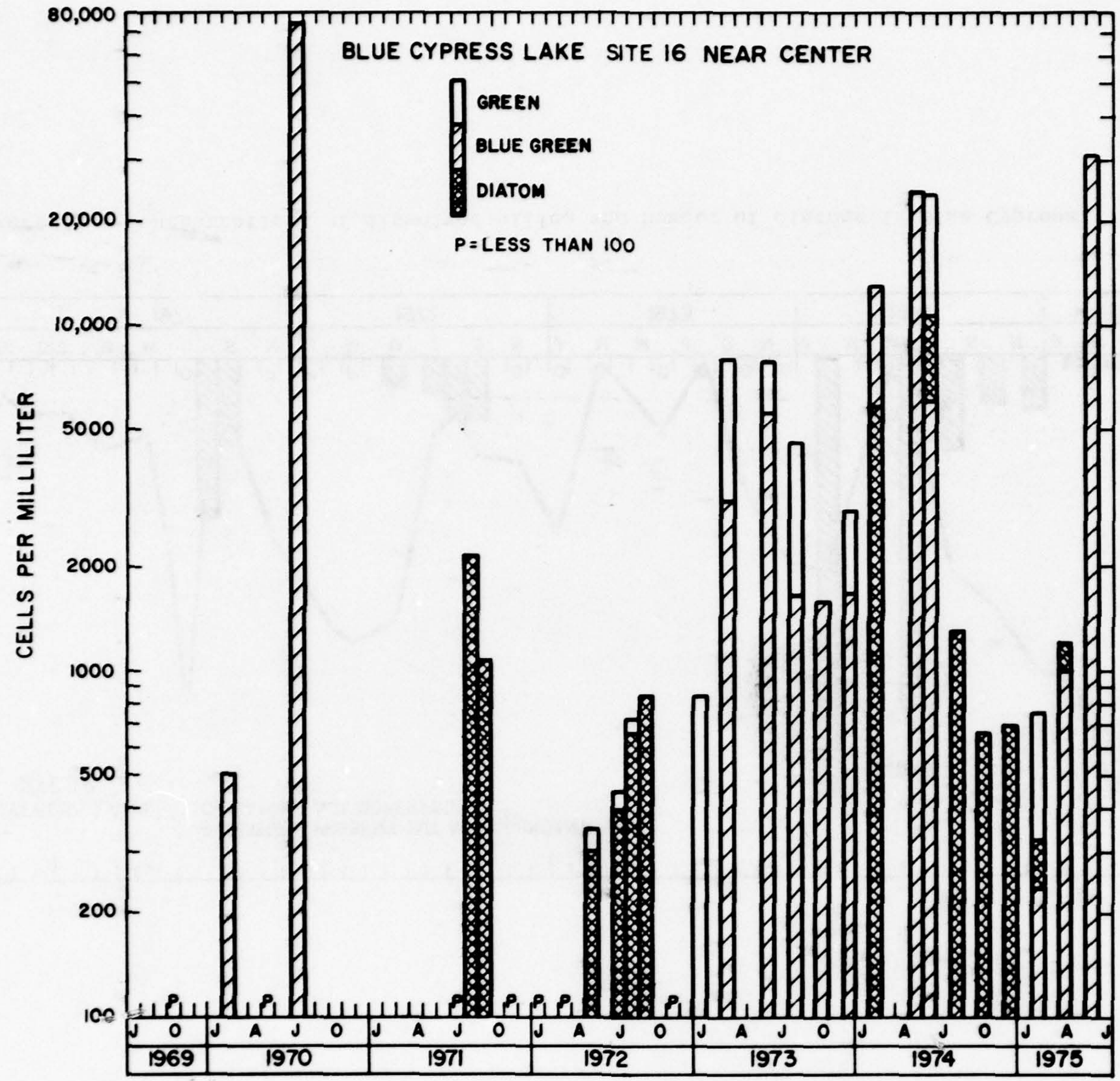

Figure 28.--Number of phytoplankton in Blue Cypress Lake.

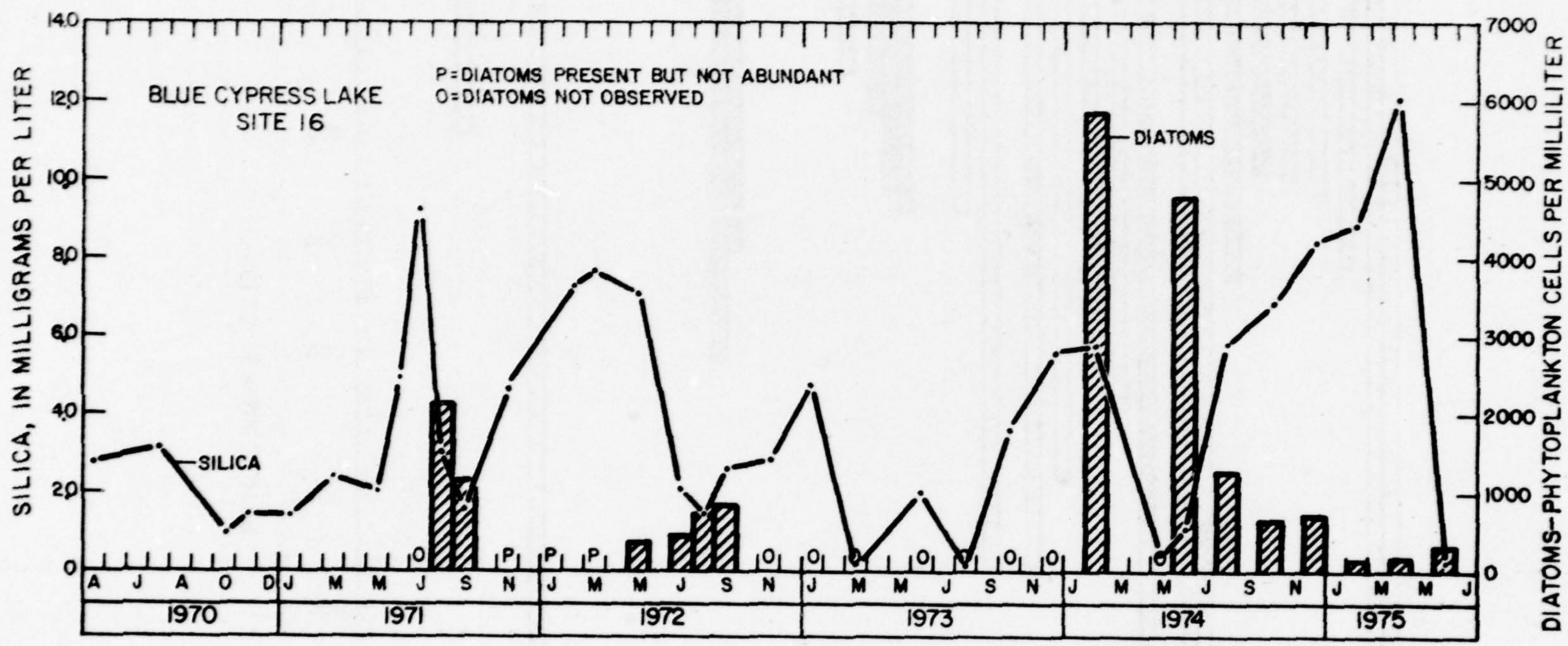

Figure 29.--Concentrations of dissolved silica and number of diatoms in Blue Cypress.

Net plankton samples were sampled in Taylor Creek Impoundment and Blue Cypress Lake between October 1969 and May 1972. Common net phytoplankton in Taylor Creek Impoundment included Volvox sp., Eudornia sp., Ceratium sp., Anacystis sp., and Melosira sp. Volvox sp. and Eudornia sp. were common in the summers of 1970, 1971, and 1972. Ceratium sp. was common in July 1971 and in May 1972. Anacystis sp. was abundant in March 1972 coincidental with another blue-green Anabaena sp. Diatoms (Melosira sp.) were dominant at other times.

Common net phytoplankton in Blue Cypress Lake included three colonial blue-greens: Aphanezomenon sp.; Anabaena sp.; and Anacystis sp.; and the filamentous diatom Melosira sp. In January 1970 Aphanezomenon sp. was abundant and was visible to the unaided eye as small greenish flakes. Anabaena sp. was abundant and visible in July 1970. Anacystis sp. was most common in May 1972. Melosira sp. was collected during all net sampling but was most numerous in May 1972.

Numbers of phytoplankton in Taylor Creek Impoundment and Blue Cypress Lake fall within the ranges of these observed in other central and southern Floridan lakes. Joyner (1974) reported that numbers of cells in Lake Okeechobee ranged from less than 50 to more than 100,000 cells/mL during January 1969 to April 1971. About 15 percent of the samples had numbers that exceeded 5,000 cells/mL and 5 percent exceeded 100,000 cells/mL. The green algae Pediastrum simplex was a dominant species in 1969, but was replaced by the blue-green alga Aphanizomenon holsaticum after January 1970. The change in the dominant species and an increased concentration of phytoplankton after 1970 in the lake followed a period of heavy inflow from rainfall and tributaries. During August 1971 through May 1972 phytoplankton concentrations in Lake Okeechobee averaged between 8,400 and 24,700 cells/mL. Aphanizomenon sp. continued to be the dominant alga in the lake (Joyner, 1974).

Davis and Marshall (1975) reported that from January 1973 to June 1974, blue-green algae (Oscillatoria sp.; Lyngbya contorta; Microcystis aeruginosa; and M. incerta) were dominant in Lake Okeechobee. They observed two pronounced maxima in phytoplankton densities, one in spring and one in autumn. Buoyant, colonial blue-green algae formed a surface scum over much of the lake from September through December 1973. The average numbers of phytoplankton ranged from 4,000 to 12,000 units/mL. Because they counted a colony or filament as a single unit, these numbers are considerably less than the number of cells per milliliter.

Lamonds (1974) found that in Lake Dicie and in Big Bass Lake in central Florida blue-green algae made up the larger portion of the phytoplankton sampled between June 1971 and April 1973. Dominant genera in Lake Dicie were Microcystis, Oscillatoria, and Aphanizomenon, sp. In Big Bass Lake Agmenellum, sp. was dominant. Concentrations ranged from about 6,000 to over 550,000 cells/mL in Lake Dicie and from about 200 to 3,600 cells/mL in Big Bass Lake.

Occasional, large blooms of phytoplankton appear to be a common phenomenon, and are not necessarily related to man's activities. For example, the large blooms in Lake Okeechobee and Blue Cypress Lake in 1970 may have resulted from the heavy rainfall and subsequent influx of nutrients into the lakes that occurred earlier that year. The algal blooms in Taylor Creek Impoundment and Blue Cypress Lake were also similar to those of other lakes in that they consisted mainly of blue-green algae.

Zooplankton

Zooplankton represent a trophic level above organic detritus, bacteria, and phytoplankton. In ponds and lakes zooplankton populations are composed mainly of rotifers, cladocerans, and copepods. Numbers of organisms usually fluctuate greatly during the year, ranging from a few to several thousand per liter or more, with highest numbers usually in fertile waters. Because of the large fluctuation in numbers that normally occur during a year, sampling to determine annual standing crop must be intensive, such as on a weekly basis. The purpose of the sampling described in this report was to provide some background information on zooplankton in the impoundment compared with that in Blue Cypress Lake.

Rotifers were the most abundant zooplankter in Taylor Creek Impoundment in 14 out of 24 samples. *Keratella* was the most common rotifer except in October 1969 when *Testudinella* was dominant. Copepods were most numerous in 4 of 24 samples and cladocera were most numerous in 6 of 24 samples. In contrast, copepods or cladocera were dominant in all 17 samples in Blue Cypress Lake. Copepods were most abundant in 14 of 17 samples. Numbers of zooplankton were on the average about 5 times more numerous in Blue Cypress Lake than in Taylor Creek Impoundment. Brezonik and others (1969) reported that the average dry weight of the rotifer *Keratella* was 0.044 μg (micrograms) compared with 0.15 μg for larval copepods. Adult copepods and cladocera of several species ranged in weight from 0.5 to 8.5 μg. Because copepods and cladocera are much larger than rotifers, the zooplankton biomass per unit volume of Blue Cypress Lake was several orders of magnitude larger than the biomass of Taylor Creek Impoundment.

The zooplankton of Blue Cypress Lake differs strikingly from that of Taylor Creek Impoundment. The relatively large biomass in the lake suggests a greater secondary production than in the impoundment. The dominance of copepods and cladocera in the lake is similar to other lakes in Florida (Brezonik and others, 1969). The dominance of rotifers in Taylor Creek Impoundment may represent an early successional phase in the impoundment, or it may reflect specific environmental conditions.

Qualitative net tows in 1970 indicated that rotifers were the dominant zooplankter in the Econlockhatchee River (Goolsby & McPherson, 1970), and copepods and cladocerans were dominant at other sites along the main stem of the upper St. Johns River. The Econlockhatchee River and the impoundment had higher organic concentrations and BODs than other sites. These conditions, and in the case of the impoundment, the anaerobic bottom waters may favor rotifers over the cladocerans and copepods.

PRIMARY PRODUCTIVITY

Primary productivity is the synthesis of inorganic nutrients into cellular organic material, mainly by photosynthesis and is an indicator of trophic status in a lake. Eutrophic lakes are highly productive; ogliotrophic lakes have low productivity. Gross productivity is the total amount of organic matter produced per unit of time. Net productivity is the amount of organic matter in plant tissue (or secreted from plant tissue) after respiration. Algae are the main primary producers in most lakes.

Primary productivity in Taylor Creek Impoundment and Blue Cypress Lake was measured periodically between July 1971 and September 1972. Data are presented in table 13. Minor inconsistencies in the data, such as slightly negative gross photosynthesis and productivity values, are due to the low sensitivity of the Winkler DO determination and sampling and measurement errors.

Primary productivity at the 1.5-ft depth ranged from 0 to 770 mg (c/m^3)/day (milligrams carbon per cubic meter per day) in the impoundment and from 0 to 1,460 mg (c/m^3)/day in Blue Cypress Lake. The average at the 1.5-ft depth was higher in the impoundment, 580 mg (c/m^3)/day, than in the lake, 345 mg (c/m^3)/day. Also, the average per unit of surface area was higher in the impoundment, (about 440 mg (c/m^2)/day) at sites in deep water, than in the lake, (about 335 mg (c/m^2)/day). Productivity was greater in the shallow water of the impoundment, averaging 630 mg (c/m^3)/day at sites 2 and 3 (1.5 ft or 0.5 m depth), than in the deep water, 475 mg (c/m^3)/day at site 1. The opposite was true for Blue Cypress Lake; productivity at 1.5 ft averaged 440 mg (c/m^3)/day near the center of the lake (site 16) and 250 mg (c/m^3)/day near the west shore (site 17). As discussed earlier, phytoplankton populations were also higher at site 16 than at site 17 in the lake. The highest productivity measured in Blue Cypress Lake was 1,460 mg (c/m^3)/day in July 1970 during a heavy algal bloom of Anabaena circinalis. Actual primary production during the bloom may have been even greater because oxygen supersaturation produced gas bubbles in the light bottle, some of which could have been lost in the measurement.

Table 13.--Primary productivity in Taylor Creek Impoundment and Blue Cypress Lake.

Date	Depth (ft)	Gross Photosynthesis mg $(O_2/L)/d$	Respiration mg $(O_2/L)/d$	Net Photosynthesis mg $(O_2/L)/d$	Gross Productivity mg $(c/m^3)/d$	Estimated[1/] Gross Productivity mg $(c/m^3)/d$
Taylor Creek Impoundment Site 1						
July 12, 1971	1.5	2.00	1.30	0.70	750	
	3.0	.25	1.40	-1.15	90	480
	6.0	.00	1.40	-1.40	0	
Aug. 23, 1971	1.5	2.05	-	-	770	
	3.0	1.15	-	-	430	700
	6.0	.00	-	-	0	
Nov. 16, 1971	1.5	.00	-	-	0	
	3.0	.15	-	-	60	50
	6.0	.00	-	-	0	
Feb. 1, 1972	1.5	.40	.15	.25	150	
	3.0	.10	.10	.00	40	130
	6.0	.15	.00	.15	-60	
Mar. 27, 1972	1.5	1.40	.70	.70	520	
	3.0	.40	.50	.10	150	400
	6.0	.10	.60	.70	-40	
May 17, 1972	1.5	2.00	1.00	1.00	750	
	3.0	.60	1.20	.60	220	700
	6.0	.05	1.00	-1.05	-20	
July 17, 1972	1.5	1.60	1.25	.35	600	
	3.0	1.25	1.40	.15	470	720
	6.0	.10	.95	.85	40	
Aug. 16, 1972	1.5	1.15	.65	.50	430	
	3.0	.50	1.00	.50	190	360
	6.0	.00	.65	.65	0	
Sept. 26, 1972	1.5	.85	.00	.85	320	
	3.0	.65	.40	.25	240	190
	6.0	.00	.55	.55	0	

1/ Estimated from graphical integration of measurements at discrete depths.

Table 13.--Primary productivity in Taylor Creek Impoundment and Blue Cypress Lake. (continued)

Date	Depth (ft)	Gross Photosynthesis mg $(O_2/L)/d$	Respiration mg $(O_2/L)/d$	Net Photosynthesis mg $(O_2/L)/d$	Gross Productivity mg $(c/m^3)/d$	Estimated 1/ Gross Productivity mg $(c/m^3)/d$
Taylor Creek Impoundment Site 2						
July 12, 1971	1.5	3.75	2.10	1.65	1400	-
Aug. 23, 1971	1.5	1.15	-	-	430	470
	3.0	1.30	-	-	490	
Nov. 16, 1971	1.5	.30	-	-	110	90
	3.0	.05	-	-	20	
Feb. 3, 1972	1.5	.05	.35	.30	20	140
	3.0	.60	.15	.45	220	
	1.5	.10	.30	.20	40	320
Mar. 27, 1972	3.0	1.50	2.70	-1.20	560	
May 17, 1972	1.5	1.80	1.75	.05	680	470
	3.0	.30	2.15	-1.83	110	
July 17, 1972	1.5	3.45	2.05	1.40	1300	980
	3.0	1.25	1.70	.45	470	
Aug. 16, 1972	1.5	2.00	.90	1.10	750	630
	3.0	.95	1.00	.05	360	
	1.5	2.40	.45	1.95	900	670
Sept. 26, 1972	3.0	.90	.50	.46	340	
Taylor Creek Impoundment Site 3						
Aug. 23, 1971	1.5	.95	-	-	360	-
Nov. 16, 1971	1.5	.45	-	-	170	-
Feb. 3, 1972	1.5	1.35	.85	.50	510	-
Mar. 27, 1972	1.5	2.60	1.80	.80	980	-
May 17, 1972	1.5	2.15	1.35	.70	810	-
July 17, 1972	1.5	3.00	1.85	1.15	1120	-
Aug. 16, 1972	1.5	1.80	.35	1.45	680	-
Sept. 26, 1972	1.5	1.20	.50	.70	450	-

1/ Estimated from graphical integration of measurements at discrete depths.

Table 13.--Primary productivity in Taylor Creek Impoundment and Blue Cypress Lake. (Continued)

Date	Depth (ft)	Gross Photosynthesis mg $(O_2/L)/d$	Respiration mg $(O_2/L)/d$	Net Photosynthesis mg $(O_2/L)/d$	Gross Productivity mg $(c/m^3)/d$	Estimated[1/] Gross Productivity mg $(c/m^3)/d$
Blue Cypress Lake Site 16						
July 14, 1971	1.5	1.80	1.00	0.80	680	470
	3.0	.10	0.90	-0.80	40	
Aug. 26, 1971	1.5	2.10	-	-	790	520
	3.0	.00	-	-	0	
Sept. 30, 1971	1.5	1.70	-	-	640	440
	3.0	.30	-	-	110	
Nov. 19, 1971	1.5	.00	-	-	0	20
	3.0	.10	-	-	40	
Feb. 1, 1972	1.5	.10	.15	.05	40	20
	3.0	.00	.10	.10	0	
Mar. 29, 1972	1.5	.55	.25	.30	210	170
	3.0	.20	.40	.20	80	
May 15, 1972	1.5	.50	.10	.60	190	370
	3.0	1.10	.20	.90	410	
July 20, 1972	1.5	1.25	.55	.70	470	350
	3.0	.30	.95	.65	110	
Aug. 17, 1972	1.5	2.35	1.45	.90	880	660
	3.0	.60	1.10	.50	220	
Sept. 27, 1972	1.5	1.20	.10	1.30	490	330
	3.0	.80	.20	.60	220	
Blue Cypress Lake Site 17						
July 22, 1970	1.5	3.4	2.2	1.2	1460	-
July 14, 1971	1.5	.90	.60	.30	340	-
Sept. 30, 1971	1.5	.70	-	-	260	-
Nov. 19, 1971	1.5	.00	-	-	0	-
Feb. 1, 1972	1.5	.10	.10	.00	40	-
Mar. 27, 1972	1.5	.55	.45	.10	210	-
May 15, 1972	1.5	.90	.25	1.15	340	-
July 20, 1972	1.5	.80	0.50	.30	300	-
Aug. 17, 1972	1.5	1.35	1.55	.20	510	-

1/ Estimated from graphical integration of measurements at discrete depths.

Most primary productivity in the impoundment and Blue Cypress Lake occurs in the upper 3 ft. In the impoundment, for example, all 9 productivity measurements made at a depth of 6 ft were zero (within experimental error). The greatly reduced productivity below 3 ft is attributed to water color, which restricts light penetration. Water in the impoundment and Blue Cypress Lake is highly colored, averaging about 130 Pt-Co units. The visibility of the secchi disc, which is limited almost entirely by color, averages only about 30 in. As cited in Vollenweider (1969) the intensity of light at the limit of visibility of the secchi disc is about 15 percent of the light intensity at the surface which indicates that probably only a small amount of light penetrates beyond 30 in.

Primary productivity varies seasonally (fig. 30) and was greatest during spring and summer when sunlight and temperature conditions were optimum. Lowest values, near zero, occurred in late autumn and winter.

The average productivity for the impoundment and Blue Cypress Lake, 580 and 345 mg (c/m^3)/day respectively was considerably lower than the average of 1,864 mg (c/m^3)/day for Lake Okeechobee reported by Davis and Marshall (1975). It is very difficult, however, to compare results obtained by different investigators unless methods are identical. Davis and Marshall incubated their samples for 6 hours at a depth of 0.7 ft whereas in this study, comparable samples were incubated for 24 hours at several depths.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates were collected with an Ekman dredge in Taylor Creek Impoundment and Blue Cypress Lake quarterly between October 1969 and July 1970 and bimonthly between July 1971 and 1972. The bottom sediments and approximate water depth at the sites are described as follows:

- Taylor Creek Impoundment
  - Site 1 Sand-silt, 20-25 ft
  - Site 2 Sand-dead vegetation (pine), 8-10 ft
  - Site 3 Sand-dead vegetation, aquatic plants, 3 ft
- Blue Cypress Lake
  - Site 16 Mud, ooze, 8-10 ft
  - Site 17 Sand, 3 ft

Figures 5 and 6 show the location of the sites.

Numbers of benthic macroinvertebrates in Taylor Creek Impoundment ranged from about 22 to $27{,}000/m^2$. Few (less than $22/m^2$) macroinvertebrates were collected in the initial sampling (site 1; October 1969 and January and April 1970), but numbers increased dramatically in July 1970 when 2,200 larvae of the phantom midge Chaoborus sp. were recorded. Chaoborus accounted for practically all the macroinvertebrates collected at sites 1 and 2 (table 14). At site 3, in shallow water, a more diverse group included oligochaetes, hirudinea, pelecypods, gastropods, amphipods, ephemerptera, and odonata, as well as Chaoborus (table 15). Larvae of

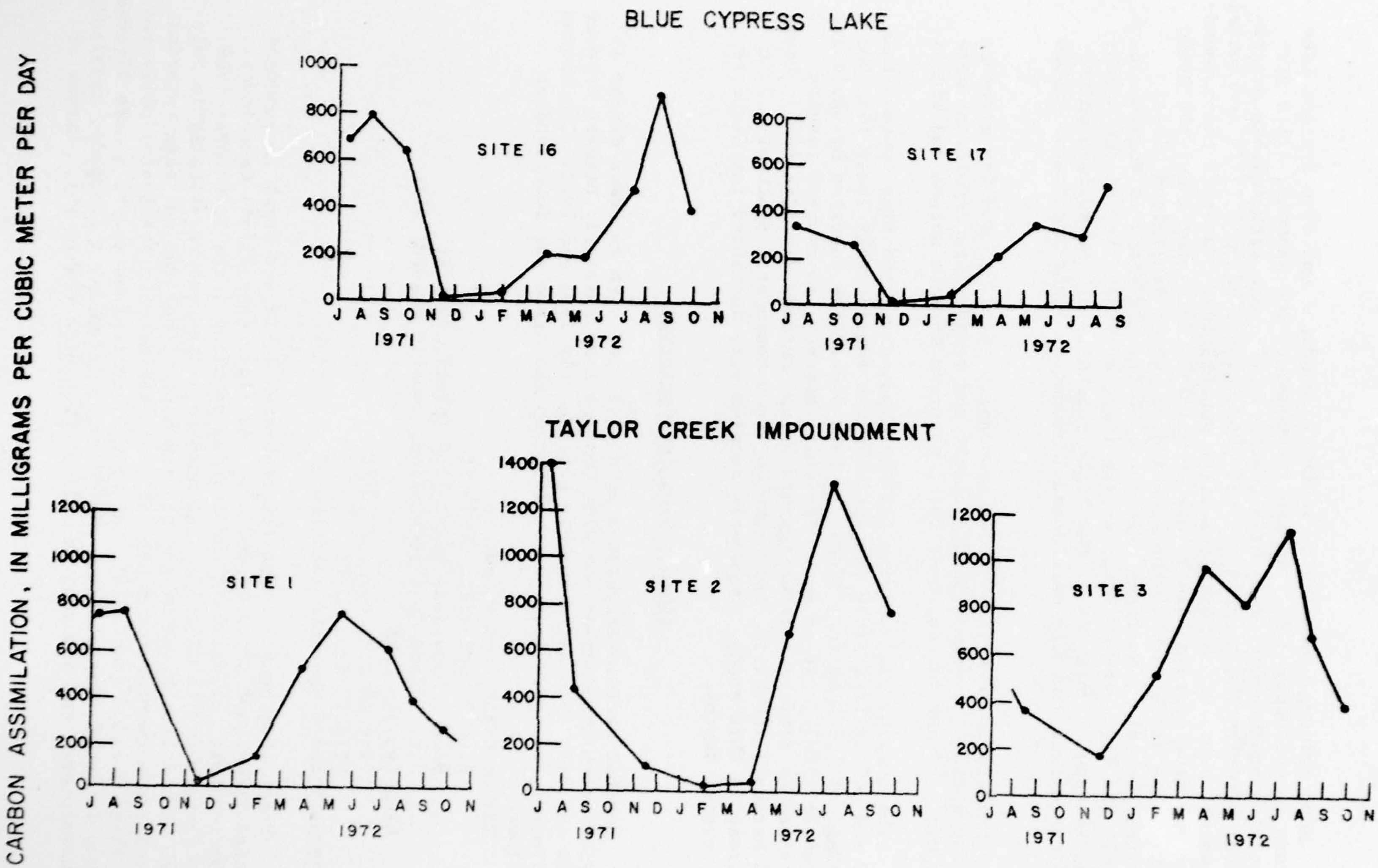

Figure 30.--Seasonal variation in primary productivity in Taylor Creek Impoundment and Blue Cypress Lake.

TABLE 14.-- Average numbers of Chaoborus sp. per square meter at three sites in Taylor Creek Impoundment

Date	Site 1	Site 2	Site 3
1969			
Oct.	0	-	-
1970			
Jan., Feb.	0	-	-
Apr., May	0	-	-
July	2,200	-	-
1971			
July	130	400	0
Aug.	720	700	44
Sept.	19,000	5,200	1,980
Nov.	27,000	7,300	440
1972			
Jan.	27,000	1,100	11
Mar.	7,700	1,400	253
May	3,400	1,200	110
July	480	1,200	22
Aug.	1,200	800	0
Sept.	1,700	1,100	22
Average, 1971-72	8,800	2,000	288

tendipedidae were generally dominant in number at site 3. The average number was 700/m².

There was a seasonal cycle in the abundance of Chaoborus in Taylor Creek Impoundment in 1971-72 (table 15). Numbers were lowest in summer and highest in autumn and winter. Chaoborus was most abundant at the deep water site with an average of $8,800/m^2$, site 1, less abundant at the site of intermediate depth with an average of $2,000/m^2$, site 2, and least abundant at the shallow water site with an average of $290/m^2$, site 3. Chaoborus was most abundant at site 3 in September 1971 ($1,980/m^2$) coincidental with relatively low DO at the site.

Numbers of benthic macroinvertebrates collected in Blue Cypress Lake in 1971-72 ranged from 210 to $5,100/m^2$ (table 16). Largest numbers were collected in July 1971. Numbers decreased appreciably at both sites in the lake in mid-winter (January-February 1972) and remained relatively low through the following summer. Oligochaets and the larvae of tendipedidae were dominant in number; pelecypods (Elliptio sp.) were dominant in biomass in the sandy substrate in the western part of the lake (site 17). In earlier sampling (1969-70) near site 17, the wet weight of pelecypods ranged from 770 to 1,200 $grams/m^2$.

Data on benthic organisms in Lake Okeechobee are available for comparison with Taylor Creek Impoundment and Blue Cypress Lake. Joyner (1974) reported that the average number of benthic macroinvertebrates sampled quarterly from January 1969 through January 1970 at 7 sites in Lake Okeechobee was $540/m^2$. In November 1971 and May 1972 the average number for 6 sites was $1,400/m^2$ and $3,300/m^2$, respectively. Oligochaetes and chironomids (Coelotanypus sp.) were the most widely distributed organisms.

Davis and Marshall (1975) reported that oligochaetes, the amphipod Gammarus fasciatus and the chironomid Pentaneurini sp. were the most common benthic invertebrates collected in Lake Okeechobee in 1973. Numbers of organisms ranged from $50/m^2$ to $2,600/m^2$.

The diversity index (Wilhm, 1970) reflects the biological community structure and the environmental controls on this structure. A low index, less than 1, generally indicates heavy organic pollution, which tends to restrict most benthic macroinvertebrate species (Slack and others, 1973, p. 25). An index between 1 and 3 generally indicates moderate pollution. A high index, greater than 3, usually indicates clean water. The value 0 means that all organisms are of the same species.

By these standards the low diversity indices in both Taylor Creek Impoundment and Blue Cypress Lake indicate organic pollution. At sites 1 and 2 in the impoundment the index was 0, reflecting the anaerobic conditions that prevailed near the bottom. Such conditions create a hostile environment where few species of benthic macroinvertebrates can

Table 15.--Average numbers of macroinvertebrates per square meter and diversity index at site 3 in Taylor Creek Impoundment.

	Total	Oligochaeta	Hirundinea	Amphipods	Decopoda (prawns)	Gastropoda	Pelecypoda	Tendipedidae	Chaoborus	Ephemeroptera	Odonata	Diversity index
July 1971	420	-	-	176	-	-	-	244	-	-	-	1.0
Aug 1971	2,021	44	15	132	15	-	-	1,742 1/	44	-	29	0.9
Sep 1971	3,058	22	-	22	-	-	-	1,034	1,980	-	-	1.0
Nov 1971	2,063	660	13	13	-	-	-	924 2/	440	13	-	1.7
Jan-Feb 1972	264	110	11	11	-	11	55	55	11	-	-	2.2
Mar 1972	3,027	11	-	319	-	-	563	1,859	253	11	11	1.6
May 1972	484	352	-	11	-	-	83 3/	33	-	-	-	1.2
July 1972	836	-	11	88	-	-	-	704	22	11	-	0.9
Aug 1972	277	-	-	-	-	-	11	255	-	-	11	0.5
Sept 1972	339	88	-	-	-	-	31	167	22	-	31	1.9
Average	1,281	129	5	77	2	1	75	702	278	4	8	1.9

1/ *Chironomus stigmaterus* (Say) identified by W. Beck

2/ *Chironomus stigmaterus* - Dominant identified by W. Beck
Glyptotendipes lobiferus

3/ *Sphaerium partumeium* (Say)

survive. Between July 1971 and September 1972 at site 3 in the impoundment, the index ranged from 0.5 to 2.2 and averaged 1.9 and in Blue Cypress Lake the index ranged from 1.3 to 2.3 and averaged 2.0.

The low diversity indices at site 3 in the impoundment and in Blue Cypress Lake probably reflect natural conditions rather than organic pollution. Values less than 3 for the diversity index are typical of much of south Florida's "natural" waters. Davis and Marshall (1975) reported that in 1973 the diversity index in Lake Okeechobee ranged between 0.6 and 2.0. Waller (1975) found a slightly larger range in the canals and marshes of the Everglades, 0.0 to 2.0.

TROPHIC STATE CHARACTERISTICS

Lakes pass through different trophic states as they age. The aging process is called eutrophication. A young lake characterized by low biological productivity, low amounts of nutrients, and by little sediment, is oligotrophic. In time, nutrients are transported into the lake by streams, runoff, rainfall, and ground water. Biological productivity increases and organic sediments build up along the shore and on the bottom. The lake is then partly enriched or mesotrophic. As aging continues, aquatic plants become more abundant and widely distributed, algal blooms become more frequent, silt and organic matter accumulate on the bottom, and nutrient content increases. The lake is then eutrophic or enriched. Aging may continue until the lake becomes a marsh or swamp. The aging process is often accelerated by man's activities, such as urbanization, deforestation, and farming.

The trophic states of Taylor Creek Impoundment and Blue Cypress Lake were evaluated by comparing these water bodies with three nearby lakes in central Florida--Lake Okeechobee, Cypress Lake, and Lake Tohopekaliga--and with five classes of trophic lakes in north-central Florida. The comparisons were made using the trophic-state indicators: nitrogen, phosphorus, specific conductance, secchi disk transparency, and the cation ratio which were used by Shannon and Brezonik (1972).

Average concentrations of ortho and total phosphorus in Lake Tohopekaliga were several times higher than concentrations in Cypress Lake, Lake Okeechobee, Blue Cypress Lake, and Taylor Creek Impoundment (table 17). Lake Tohopekaliga is several miles south of Orlando and has suffered cultural eutrophication resulting from sewage treatment plants that have discharged large amounts of waste into its northern tributaries. In 1974, for example, these treatment plants discharged five billion gallons of water into Lake Tohopekaliga's tributaries, with the resulting input of 300 tons of nitrogen and 670 tons of phosphate-phosphorus into the lake (Florida Game and Fresh Water Fish Commission, 1974).

Of the five water bodies listed in table 17, Taylor Creek Impoundment had the second highest average concentration of phosphorus. This was because some samples were from the deep, anaerobic waters that had

Table 16.--Average numbers of macroinvertebrates per square meter collected with an Ekman dredge in Blue Cypress Lake.

Date	Oligochaeta	Hirudinea	Amphipoda	Gastropoda	Pelecypoda	Tendipedidae	Ephemeroptera	Odonata	Trichoptera	Chaoborus	Diversity Index	Total
					SITE 16 (Center of Lake)							
July 1971	350	88	400	350	130	3,800	-	-	-	-	1.4	5,100
Aug	22	33	110	33	11	460	-	-	-	-	1.5	670
Sept	280	100	44	29	14	190	-	-	-	-	2.0	660
Nov	88	88	44	-	130	120	13	-	-	44	2.3	760
Jan-Feb 1972	110	11	11	11	55	55	-	-	-	11	2.2	260
Mar	55	-	11	-	22	55	-	-	-	-	1.8	140
May	210	44	44	33[b]	-	66	-	-	-	22	2.1	420
July	310	-	22	22[b]	-	22	-	-	-	53	1.4	430
Aug	130	-	-	-	11	53	-	-	-	97	1.7	290
Sept	230	11	44	53[b]	-	123	-	-	-	211	2.2	670
Average	180	38	73	53	38	521	1			44	1.9	950
					SITE 17 (Near West Shore)							
July 1971	1,500	44	200	180	180	1,600[c]	-	-	-	-	1.8	3,700
Aug	530	44	33	55	220	200	-	22	22	-	2.2	1,100
Sept	310	55	66	22	230	110	22	-	-	-	2.3	810
Nov	1,800	44	130	13	88	440[a]	-	-	-	-	1.3	2,600
Jan-Feb 1972	22	44	-	-	77	66	-	-	-	-	1.9	210
Mar	33	11	88	-	110	11	-	-	-	-	1.8	250
May	130	22	290	-	77	99	-	-	-	-	2.0	620
July	220	11	22	-	31	22	-	-	-	-	1.4	310
Aug	210	35	-	-	35	22	-	-	-	-	1.4	300
Sept	110	22	-	-	22	55	-	-	-	-	1.9	220
Average	490	33	82	27	110	260	2	3	2	2	2.0	1,010

a/ Coclotanypus sp.
W. Beck

b/ Vivaparus georgianus (Tyron)

c/ Glyptotendipes lobiferus (Say)
Chironomus crassicaudatus (Mall.)
identified by William Beck

Table 17.--Average nitrogen, and phosphorus concentrations and specific conductance at Taylor Creek Impoundment and Blue Cypress Lake, Upper St. Johns River basin and Cypress Lake, Lake Okeechobee, and Lake Tohopekaliga, Okeechobee-Kissimmee basin.

	Total ortho-phosphorus (P)	Total phosphorus mg/L (P)	Total organic nitrogen (N)	Total nitrogen (N)	Specific conductance umhos/cm
Taylor Creek Imp.					
All sites	0.06	0.09	1.05	1.22	106
Site 3	.03	.05	.98	1.05	96
(1969-75)					
Blue Cypress Lake					
All sites (1969-75)	.04	.05	1.2	1.4	248
Cypress Lake 1/					
(1970-75)	.03	.07	1.4	1.8	
(1954-64)					74
(1964-75)					130
Lake Okeechobee 2/ (1969-72)	.03	.05	1.3	1.4	517
Lake Tohopekaliga 3/					
Pre-drawdown, (1970-71)	.19	.31	.85	--	129
After drawdown (1972-74)	.15	.46	1.30	--	179

1/ From Gaggiani and McPherson, 1978.
2/ From Joyner, 1974.
3/ From Florida Game and Fresh Water Fish Commission, 1974.

relatively high phosphorus concentrations. This phosphorus data cannot be used in the trophic state comparison with other sites. The average concentration of phosphorus at site 3 in the impoundment, which was a shallow-water site, was about half the overall average for the impoundment.

The average specific conductance for the five water bodies presented in table 17 ranged from 74 umhos/cm in Cypress Lake (1954-64) to 517 umhos/cm in Lake Okeechobee (1969-72). Long-term data (Gaggiani and McPherson, 1978) from Cypress Lake, however, indicates that the specific conductance almost doubled over the last 20 years. Taylor Creek Impoundment had the lowest specific conductance, averaging about 100 umhos/cm. Blue Cypress Lake had the second highest specific conductance, 248 umhos/cm, probably attributable to intensive agricultural development around the lake. The specific conductance of the water in Lake Okeechobee is high because of the mineral-rich waters that are pumped into the lake from agricultural lands (Joyner, 1974).

Algal blooms occur periodically in Florida lakes. Only where blooms are persistent or continuous are the lakes considered eutrophic. An increasing frequency of algal blooms or changes in the species that bloom, however, can indicate changing trophic conditions. Algal blooms occurred in Taylor Creek Impoundment and Blue Cypress Lake, but their frequency was relatively low and do not suggest eutrophic conditions. Blue-green algae, which are often indicative of eutrophic lakes, became dominant in Blue Cypress Lake in a bloom in the summer of 1970. Blooms of blue-green algae also occurred in 1970 in Lake Okeechobee (Joyner, 1974) and Lake Tohopekaliga (Fla. Game and Fresh Water Fish Commission, 1974). All these blooms followed a period of greater than normal rainfall and runoff, that increased nutrient input to lakes.

Shannon and Brezonik (1972) analyzed 55 lakes from north-central Florida. They divided these lakes into four basic categories: (1) clear alkaline; (2) clear soft; (3) colored acid; and (4) colored alkaline. The clear lakes and the colored lakes then were divided separately into trophic groups. The clear lakes formed three apparently natural groups interpreted as the classical trophic categories--oligotrophic, mesotrophic, and eutrophic. The colored lakes were more variable and less easily interpretable in terms of classical groupings. Shannon and Brezonik (1972) divided colored lakes into five trophic groups as: (1) oligotrophic, (2) meso-eutrophic, (3) oligo-mesotrophic, (4) dystrophic, and (5) residual.

Blue Cypress Lake and Taylor Creek Impoundment are compared with the basic lake categories of Shannon and Brezonik (1972) in table 18, and with these investigators trophic groupings of lakes in table 19. Both the lake and the impoundment fall into the category of a colored, alkaline water body. The color of each was about 130 platinum-cobalt units, and the alkalinity averaged 32.0 mg/L in the lake and 22.1 mg/L in the impoundment. The lake and the impoundment, however, do not

correspond to any of the Shannon and Brezonik's (1972) five trophic groups for colored lakes (table 19). The most probable reasons for this are (1) the geology and soils in the Blue Cypress Lake and Taylor Creek basins are different from those in the lake basins in the Shannon and Brezonik (1972) study and, (2) the lake and the impoundment have been altered to a large degree by man's activities. Both of these affect the water chemistry. Of the indices used to characterize the five trophic groups, the concentrations of phosphorus and organic nitrogen, the inverse secchi disk value (transparency), and the cation ratio could be interpreted to indicate the lake and impoundment are either meso-eutrophic or oligo-mesotrophic. However, the specific conductances in the lake and in the impoundment far exceed any of the values for the five trophic groups (table 19).

On the basis of the chemical and biological data collected in this study, Blue Cypress Lake and Taylor Creek Impoundment are best classified as mesotrophic or partly enriched. Although the impoundment is of recent origin, it cannot be called oligotrophic, and apparently it did not pass through an oligotrophic state. Immediately after construction of the impoundment, extreme environmental perturbations indicated a state of disequilibrium. The environmental perturbations became less severe in subsequent years, and nutrient concentrations and biological productivity sometimes exceeded those in Blue Cypress Lake. An important source of the nutrients that sustained biological production was the flooded vegetation and soil. The availability of nutrients from this source probably prevented the impoundment from passing through an oligotrophic state.

EFFECTS OF IMPOUNDMENT ON DOWNSTREAM WATER QUALITY

Ten downstream sampling profiles were made between Taylor Creek Impoundment and the St. Johns River at Highway 520 in 1971 and 1972 to study the short-term effects of water releases on downstream water quality. Observations were made with water being released from the top of the impoundment through the spillway gate and from the bottom of the impoundment through the bottom low-flow culverts. Releases were made during periods of both stratification and nonstratification in the impoundment. The dates and discharge from the impoundment during the profiles are as follows:

Date	Discharge (ft^3/s)	Type of release
11/17/71	127	Bottom
02/03/72	15.0	do
03/28/72	3.76	do
05/17/72	3.79	do
05/18/72	158	Top
05/19/72	169	Bottom
07/18/72	286	do
08/14/72	193	Top
09/28/72	376	do

Water samples were collected at 5 sites along the downstream profiles (fig. 5):

10. Taylor Creek below S-164,
11. Taylor Creek at Highway 532,
12. Taylor Creek at Lake Poinsett,
13. Lake Poinsett above Taylor Creek inflow,
15. St. Johns River at Highway 520 below Taylor Creek inflow.

The analyses showed that a considerable amount of aeration resulted when water was released from either the top or the bottom of Structure-164. At high discharges, however, it appeared that a top release resulted in a somewhat higher DO than a bottom release. On several occasions the DO was higher below S-164, because of aeration, than in the surface waters of the impoundment. DO concentrations below S-164 (site 10) during the 10 profiles ranged from 4.6 to 8.0 mg/L and averaged about 6.0 mg/L.

The DO at Highway 532 (site 11) ranged from 3.7 to 6.5 mg/L and averaged 5.0 mg/L, slightly lower than below S-164 (site 10). The decrease between S-164 and Highway 532 could have been at least partly due to oxidation of sulfides, organic material, ferrous iron, and oxygen uptake by bottom sediments in the swamp between the two stations. At the mouth of Taylor Creek (site 12) the average and range in DO concentration was about the same as below S-164 (site 10). For comparison, during the same period that the profiles were made, the DO in Jane Green Creek ranged from 1.0 to 4.7 mg/L with an average of 2.8 mg/L and at the St. Johns River at Highway 520 (outlet of Lake Poinsett, site 15), DO ranged from 4.9 to 8.7 mg/L and averaged 7.0 mg/L.

At high discharge from either the top or bottom of the impoundment the total phosphorus concentration in water released from the impoundment averaged 0.055 mg/L, and was about the same as the average for 20 samples from Jane Green Creek (0.050 mg/L). At low discharge with a bottom release, however, total phosphorus increased in concentration below S-164 (range 0.062 to 0.087 mg/L) because a large percentage of the water came from near the bottom of the impoundment where nutrients are generally in much higher concentrations than in the surface waters of the impoundment. At the mouth of Taylor Creek (site 12) during a low discharge bottom release the phosphorus concentration was generally less than below S-164. At high discharge there was little downstream change in phosphorus concentrations. Phosphorus concentrations in Lake Poinsett and the St. Johns River were generally higher than in Taylor Creek. The phosphorus concentration in 10 samples collected at the outlet of Lake Poinsett (site 15) averaged 0.065 mg/L and ranged from 0.020 to 0.160 mg/L.

Table 18.--Selected chemical characteristics of Taylor Creek Impoundment, Blue Cypress Lake, and four general lake types in north-central Florida (Shannon and Brezonik, 1972). Values are averages unless otherwise noted.

Constituent or property	General Lake Types[1]				Taylor Creek Impoundment	Blue Cypress Lake[2]
	Colored		Clear			
	Acid	Alkaline	Alkaline	Soft water		
pH (units)	5.66	7.63	8.38	5.83	6.7	7.6
Alkalinity; mg/L as $CaCO_3$	2.36	11.7	92.14	2.80	22.1	32.0
Sp. conductance umhos/cm at 25°C	45.8	70.0	249	48.2	106	248
Color as platinum-Cobalt units	220	114	60	17	130	128
Calcium, mg/L	3.3	6.9	36.8	3.0	9.1	17.5

1 From Shannon and Brezonik, 1972.
2 Median values.

Table 19.--Trophic state indicators for colored lakes of north-central Florida (Shannon and Brezonik, 1972) and for Blue Cypress Lake, Taylor Creek Impoundment. Numbers are means, except those in, parenthesis, which are standard deviations.

	Total phosphorus (mg/L as P)	Total organic-N (mg/L as N)	Inverse secchi disk transparency m^{-1}	Sp. conductance unhos/cm at 25°C	Cation ratio Mg + Ca/Na + K millimoles/L
Oligotrophic	0.032	0.70	0.67	48.0	0.60
	(0.017)	(0.10)	(0.06)	(5.1)	(0.17)
Meso-eutrophic	.060	1.24	1.07	82.2	1.21
	(.003)	(.25)	(.11)	(6.8)	(.28)
Oligo-mesotrophic	.058	.72	1.24	47.6	.60
	(.035)	(.17)	(.25)	(6.6)	(.16)
Dystrophic	.213	1.36	1.59	46.0	1.36
	(.278)	(1.45)	(2.41)	(49.0)	(1.57)
Residual	.211	1.13	1.54	64.2	1.67
	(.152)	(.68)	(.96)	(33.0)	(1.95)
Taylor Creek Impoundment	.088	1.05	1.38	106	.72
	(.095)	(.48)	(-)	(25)	(-)
Blue Cypress Lake	.053	1.25	1.22	248	.59
	(.020)	(.45)	(-)	(46)	(-)

AD-A073 460 GEOLOGICAL SURVEY TALLAHASSEE FLA WATER RESOURCES DIV F/G 8/8
LIMNOLOGY OF TAYLOR CREEK IMPOUNDMENT WITH REFERENCE TO OTHER W--ETC(U)
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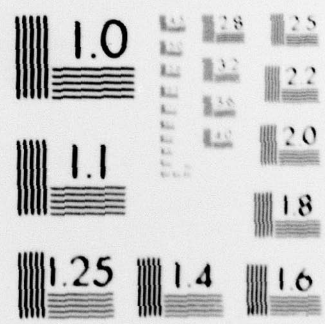
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Inorganic nitrogen, like phosphorus, was higher in concentration at low discharge than at high discharge. The average concentration below S-164 (0.16 mg/L) was twice as high as in Jane Green Creek (0.08 mg/L) and slightly higher than the average at Highway 520 (0.13 mg/L). At low discharge there appears to be a downstream decrease in inorganic nitrogen, whereas, at high discharge there is little downstream change.

There was considerable variation in organic nitrogen concentration and no consistent pattern was evident. The concentration in water released from the impoundment was similar to other sites sampled with the exception of Wolf Creek which had a consistently lower concentration.

Color, TOC, BOD, trace metals, and alkalinity varied little along the profiles. A high discharge from Taylor Creek, however, resulted in a considerable sediment input into Lake Poinsett when the lake was at low stage. This is evidently caused by shallow water and high velocities at the mouth of Taylor Creek. On May 19, 1972 the suspended sediment concentration at the mouth of Taylor Creek was 1,340 mg/L and the turbidity was evident several hundred yards out into the lake. Suspended sediment concentration is normally less than 10 mg/L. During the September 1972 profile more than half of the total phosphorus in the water column (0.085 mg/L) near the outlet of Lake Poinsett was associated with this suspended sediment, that is, it was in suspension rather than in solution.

The dissolved solids concentration (sum of constituents) of water in Taylor Creek Impoundment ranged from 41 to 85 mg/L (table 7) and in the St. Johns River at site 15 from about 250 mg/L to more than 1,200 mg/L. Under appropriate conditions such as high discharge from Taylor Creek and low to moderate discharge in the St. Johns River, the Taylor Creek inflow reduces the dissolved solids concentration in the St. Johns River by dilution.

The number of algae decreased markedly in Taylor Creek below the impoundment (table 20). During low discharge of a few cubic feet per second few algae were observed downstream of S-164, even though large numbers were present in the impoundment, as in March 1972. During high discharge however, algae were transported downstream in detectable numbers to the outlet. For example, the diatom, Melosira, was abundant in the impoundment on July 18, 1972. Though somewhat reduced in number, it was present throughout the creek below the impoundment during a bottom release on this date (table 20).

Variations in specific conductance, silica, nitrogen, and phosphorus between 1971 and 1975 below S-164 (site 10) are shown in figure 31. Specific conductance was highest when little or no water was released from the impoundment. Variations in silica, nitrogen, and phosphorus are similar to variations observed in the impoundment.

Table 20.--Numbers of planktonic algae (cells/mL) in Taylor Creek and Lake Poinsett. (N, none observed; P, present but less than 20 per ml; discharge data on days of plankton sampling).

Date	Discharge from top or bottom (ft^3/s)	Dominant algae	Site 3	Site 2	Site 1	Below S-164 (Site 10)	Hwy 532 (Site 11)	Outlet at Poinsett (Site 15)	Lake Poinsett (Site 13)
Nov. 17, 1971	127 (bottom)	a/	48	22	57	21	13	-	394 (diatoms)
Feb. 3, 1972	15.0 (bottom)	Anabaena	2,145	-	N	435	P	-	-
		Melosira	760	-	947	348	15	-	-
Mar. 28, 1972	3.76 (bottom)	Anabaena	32,000	33,740	30,400	4,070	151	N	-
		Melosira	480	228	P	P	P	N	-
May 17, 1972	3.79 (bottom)	Anabaena	40	446	432	P	P	N	7,680
May 18, 1972	158 (top)	Melosira	2,511	7,128	4,480	1,328	24	N	N
May 19, 1972	169 (bottom)	Ceratium	10	33	42	N	N	N	N
July 18, 1972	286 (bottom)	Melosira	1,096	1,900	1,840	856	818	150	150
Aug. 14, 1972	193 (top)	Phormidium (?)	3,000	2,400	1,920	1,760	720	16	N
		Anabaena	244	320	160	320	270	20	N
		Melosira	240	368	520	560	539	162	23

a/ Dominant algae not determined

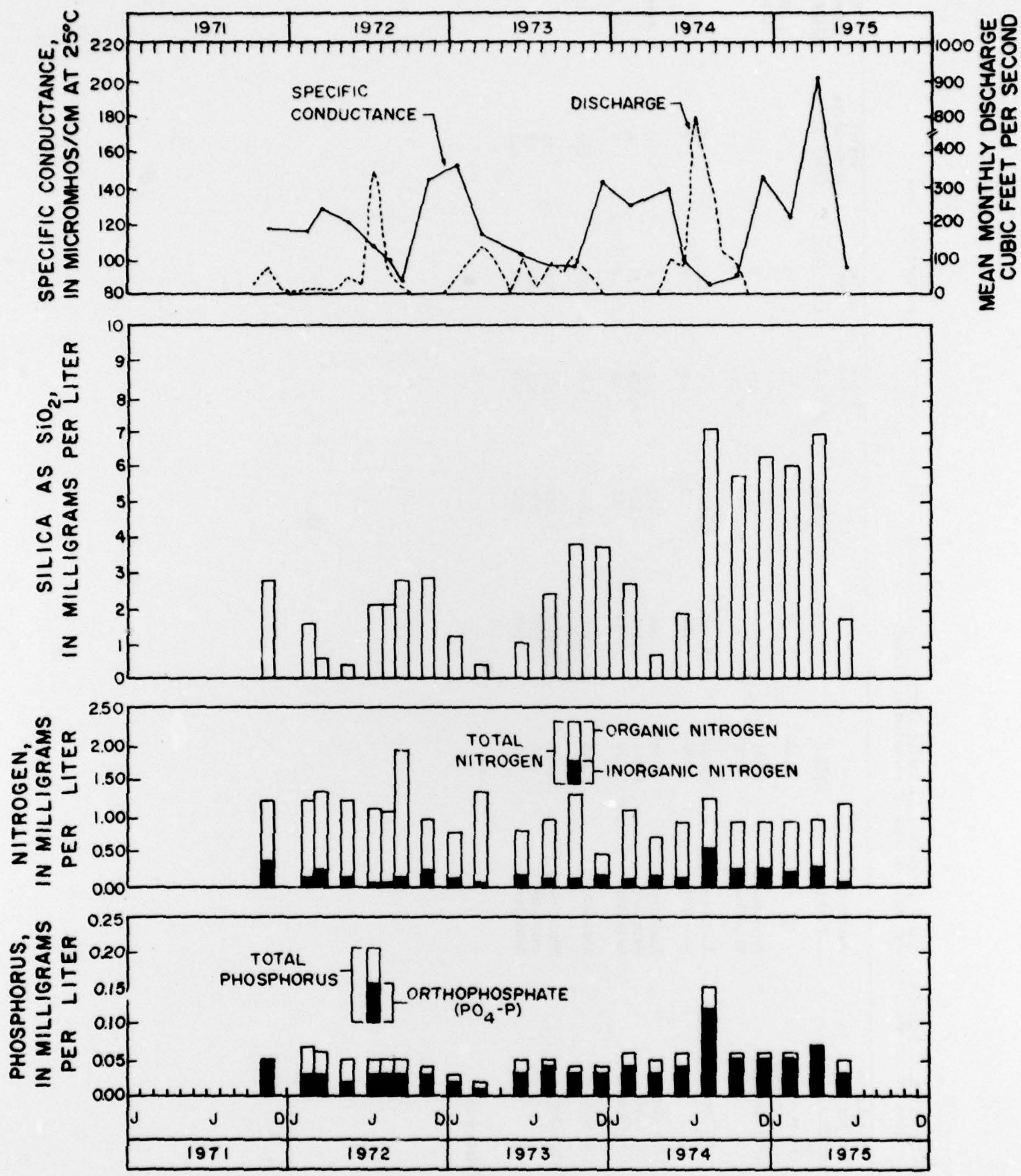

Figure 31.--Variations in specific conductance, silica, nitrogen, and phosphorus in Taylor Creek below S-164.

Table 21 gives the mean values for selected water-quality parameters in Taylor Creek below S-164 (site 10) Wolf Creek (site 22) and Jane Green Creek (site 23). A comparison of these data shows that water released from the impoundment is similar in quality to the two nearby unregulated streams. Of the 21 parameters shown in the table, only ammonia indicates poorer water quality than in the two creeks. Ammonia averaged 0.12 mg/L below S-164 as compared with 0.05 and 0.06 mg/L respectively in Wolf and Jane Green Creeks. However, water below S-164 was higher in DO (6.7 mg/L) than in either Wolf Creek (6.0 mg/L) or Jane Green Creek (3.7 mg/L). Also, concentrations of the major constituents were lower in Taylor Creek below S-164 as indicated by the lower dissolved solids, hardness, bicarbonate, and specific conductance, than in Wolf and Jane Green Creeks.

SUMMARY AND CONCLUSIONS

Taylor Creek Impoundment was constructed on the western side of the upper St. Johns River basin as part of a plan for flood control and water regulation. The impoundment, initially filled in the fall of 1969, has a volume of about 26,000 acre-ft and a surface area of about 4,000 acres. Limnological data were collected in the impoundment through periodic monitoring and through an intensive investigation between July 1969 and July 1975. Concurrent comparative limnological data were collected in Blue Cypress Lake, a somewhat larger (6,300 acres) natural reservoir in the headwaters of the St. Johns River basin. Some of the findings from these studies are summarized below.

The impoundment with a drainage area to volume ratio of 1.3 receives less inflow per unit lake volume than does Blue Cypress Lake which has a ratio of 2.3. The waters of both Blue Cypress Lake and the impoundment are replaced, on the average, about 2 times per year. Even though Blue Cypress Lake has a considerably larger surface area, the impoundment has a 50 percent longer shoreline because of shoreline irregularity, giving the impoundment more littoral zone area for aquatic productivity.

Chemical and thermal stratification are characteristics which most clearly distinguish the impoundment from Blue Cypress Lake and other water bodies in the area. Stratification occurs in the impoundment because of its greater depth and poor mixing. Stratification begins in late winter and lasts until early autumn. Chemical stratification occurs as a result of thermal stratification which prevents the upper waters of the impoundment from mixing with the deeper water. As a result, organic matter produced in the epilimnion by photosynthesis dies and settles into the hypolimnion, where it undergoes bacterial decomposition which consumes oxygen. Trees and brush killed in flooding are also a source of organic matter, particularly so during the early years of impoundment. Concentrations of DO decreased sharply at the thermocline; during the summers of 1970-72 concentrations decreased to zero at depths of 8 to 10 ft.

Numerous other chemical and physical characteristics of the impoundment are associated with stratification. The Eh decreased from 400 to 600 mv in the epilimnion to 0 to -200 mv in the hypolimnion and the pH decreased from about 6.5 to less than 6.0. The hypolimnion also has high concentrations of orthophosphate, ammonia-N, silica, bicarbonate, carbon dioxide, iron, manganese and hydrogen sulfide, all of which can be attributed to the anaerobic environment.

The impoundment turns over in the autumn and becomes vertically homogeneous. In contrast, Blue Cypress Lake remains well-mixed throughout the year.

DO concentrations in the upper water of the impoundment varied as much as 2 to 4 mg/L daily and from less than 1 to more than 8 mg/L annually. Daily variations in Blue Cypress Lake were generally less than 2 mg/L and annually concentrations ranged from 5 to 10 mg/L.

A long-term increase in DO has occurred in the impoundment since 1970. The depth to the top of the anaerobic zone has increased gradually each year from about 6 ft in 1970 to 12 ft in 1974. Also the length of time anaerobic conditions prevailed decreased from about 7 months in 1970 and 1971 to less that 2 months in 1974.

Total nitrogen, which was 85 to 90 percent organic nitrogen, averaged about 1.2 mg/L in the impoundment and 1.4 mg/L in Blue Cypress Lake. The remaining inorganic N was mostly ammonia in the impoundment and mostly nitrate in Blue Cypress Lake. Total phosphorus concentrations averaged 0.105 mg/L at the deep water site and 0.046 mg/L in the littoral area of the impoundment and 0.053 mg/L in Blue Cypress Lake. From 60 to 75 percent of the phosphorus was orthophosphate. Except for phosphorus concentrations in the hypolimnion of the impoundment, the nitrogen and phosphorus values are within the ranges measured in nearby unregulated streams in the upper St. Johns basin and in Lake Okeechobee. From 1970 to 1974, phosphorus concentrations in the impoundment decreased about 50 percent.

During the growing season inorganic nitrogen is virtually depleted from the epilimnion. The inorganic nitrogen-to-phosphorus molar ratio decreases to less than 3, suggesting that nitrogen may be a growth limiting nutrient.

Concentrations of silica in both the impoundment and Blue Cypress Lake ranged from near 0 to more than 6 mg/L. Silica concentrations were lowest in the spring and summer and highest in the autumn and winter. The large variations were probably caused by the growth and decay of diatoms.

Table 21.--Mean values for selected water-quality parameters in Taylor Creek below S-164, Wolf Creek and Jane Green Creek.

Constituent or property	Taylor Creek below S-164		Wolf Creek		Jane Green Creek	
	Number of samples	Mean	Number of samples	Mean	Number of samples	Mean
Specific conductance (umhos/cm)	25	120	30	195	29	162
Dissolved oxygen (mg/L)	25	6.7	29	6.0	34	3.7
pH (units)	24	6.8	27	7.1	29	6.9
Bicarbonate (mg/L)	22	29	27	67	29	37
5-day BOD (mg/L)	24	1.1	24	1.2	28	1.4
Organic carbon (mg/L)	24	17	24	19	28	25
Nitrate-nitrogen (mg/L)	25	.03	28	.02	38	.02
Nitrite-nitrogen (mg/L)	25	.01	28	.01	38	.01
Ammonia nitrogen (mg/L)	25	.12	28	.05	38	.06
Organic nitrogen (mg/L)	25	.90	28	.76	38	1.09
Orthophosphate-P (mg/L)	25	.042	28	.063	38	.039
Total phosphorus P (mg/L)	25	.058	28	.084	35	.053
Silica (SiO_2) (mg/L)	25	2.7	30	6.2	35	4.0
Dissolved solids residue (mg/L)	8	89	11	129	15	140
Hardness as $CaCO_3$ (mg/L)	8	32	12	60	16	49
Dissolved iron (µg/L)	12	202	12	251	17	276
Total iron (µg/L)	13	342	8	596	11	414
Total lead (µg/L)	9	3.3	7	27	10	9.2
Dissolved manganese (µg/L)	8	22	8	10	13	27
Total manganese (µg/L)	10	21	8	11	10	25
Total zinc (µg/L)	8	8.8	6	23	11	21

Total organic carbon and BOD values averaged 18 and 1.6 mg/L respectively in the impoundment and 22 and 1.1 mg/L respectively in Blue Cypress Lake. The TOC analyses suggest an average concentration of organic material of 35 to 45 mg/L.

Water in the impoundment and Blue Cypress Lake is of a mixed chemical type with calcium, sodium, bicarbonate, and chloride as the dominant ions. Water in the impoundment is soft whereas water in Blue Cypress Lake varies from soft to moderately hard. Concentrations of all major ions, except sulfate, have decreased in the impoundment since 1970. Sulfate concentrations have increased slightly in the impoundment with concentrations becoming similar to those in the inflowing creeks. Concentrations of the major ions in Blue Cypress Lake varied in response to hydrologic and climatic conditions and were generally inversely related to lake stage.

The mean concentrations of trace metals, except iron, were several times to an order of magnitude lower than recommended water quality criteria for various uses. Iron concentrations exceeded the criterion for public supplies partly because of anaerobic conditions in the impoundment and partly because of relatively high iron concentations that occur naturally in the basin.

The overall quality of water in the impoundment has gradually improved since 1970, probably due to the leaching and gradual flushing of organic material, nutrients and inorganic material from the inundated soil and terrestrial vegetation of the impoundment.

The numbers of planktonic algae in the impoundment ranged from 20 to about 100,000 cells/mL. Blue-green algae and diatoms were the dominant divisions. Numbers of phytoplaknton were correlated positively with temperature, BOD, bicarbonate, organic nitrogen, and potassium. Phytoplankton in Blue Cypress Lake were generally less abundant than in the impoundment. Total numbers ranged from about 20/mL to 74,480/mL and exceeded 10,000 cells/mL during only 5 sampling periods. Diatoms dominated about 50 percent of the samples. Phytoplankton numbers in the lake correlated negatively with silica and orthophosphate. The numbers of phytoplankton in the impoundment and Blue Cypress Lake fall within the ranges observed in other large lakes in central and southern Florida.

In 1971 and 1972, primary productivity was higher in Taylor Creek Impoundment than in Blue Cypress Lake. Productivity at the 1.5-ft depth averaged 580 mg (c/m^3)/day in the impoundment and 345 mg (c/m^3)/day in Blue Cypress Lake. Seasonally, primary productivity varied from 0 to 770 in the impoundment and from 0 to 1,460 mg (c/m^3)/day in Blue Cypress Lake. Values were highest in late spring and summer. In both water bodies, primary productivity is limited to the upper 3 ft because the highly colored water restricts light penetrations.

Numbers of zooplankton were, on the average, about 5 times more abundant in Blue Cypress Lake than in the impoundment. Copepods and cladocera were dominant in the lake, and rotifers were dominant in the impoundment. Because copepods and cladocera are much larger than rotifers, the zooplankton, biomass in Blue Cypress Lake was several orders of magnitude larger than in the impoundment.

Numbers of benthic macroinvertebrates ranged from about 22 to 27,000/m^2 in the impoundment during 1971-1972. At the deep water sites these consisted almost entirely of the phantom midge Chaoborus, which averaged more than 8,000/m^2 at site 1 and 1,980/m^2 at site 2. In shallow water, site 3, a variety of macroinvertebrates was collected, with an average of greater than 1,000/m^2. Larvae of tendipedidae and phantom midges dominated. For comparison, numbers of macroinvertebrates in Blue Cypress Lake during this period ranged from about 200/m^2 to more than 5,000/m^2 and averaged about 1,000/m^2. Oligochaetes and the larvae of tendipedidae dominated in number. Pelecypods (Elliptio) dominated in biomass in the sandy substrata in the western part of the lake.

The quality of water released from the impoundment during the period of this study was comparable to that of two nearby unregulated creeks, Wolf Creek and Jane Green Creek. Of 21 physical, organic, and inorganic parameters only ammonia indicated poorer quality. Ammonia averaged 0.12 mg/L for water released from the impoundment as compared with an average of 0.05 to 0.06 mg/L in Wolf and Jane Green Creeks. The average DO concentration below the impoundment was higher, 6.7 mg/L, than in either Wolf Creek (6.0 mg/L) or Jane Green Creek (3.7 mg/L) and the concentrations of major chemical constituents were lower. The major adverse downstream effect noted in 10 downstream profiles made under various discharge conditions was an increase in suspended sediment concentration in the lower end of Lake Poinsett. This was caused by a low stage in Lake Poinsett and also water of high velocity near the mouth of Taylor Creek which resuspended lake bottom sediment.

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